ANDROLOGY ORIGINAL ARTICLE

Use of laptop computers connected to internet through Wi-Fi decreases human sperm motility and increases sperm DNA fragmentation

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Objective: To evaluate the effects of laptop computers connected to local area networks wirelessly (Wi-Fi) on human spermatozoa.
Design: Prospective in vitro study.
Setting: Center for reproductive medicine.
Patient(s): Semen samples from 29 healthy donors.
Intervention(s): Motile sperm were selected by swim up. Each sperm suspension was divided into two aliquots. One sperm aliquot (experimental) from each patient was exposed to an internet-connected laptop by Wi-Fi for 4 hours, whereas the second aliquot (unexposed) was used as control, incubated under identical conditions without being exposed to the laptop.
Main Outcome Measure(s): Evaluation of sperm motility, viability, and DNA fragmentation.
Result(s): Donor sperm samples, mostly normozoospermic, exposed ex vivo during 4 hours to a wireless internet-connected laptop showed a significant decrease in progressive sperm motility and an increase in sperm DNA fragmentation. Levels of dead sperm showed no significant differences between the two groups.
Conclusion(s): To our knowledge, this is the first study to evaluate the direct impact of laptop use on human spermatozoa. Ex vivo exposure of human spermatozoa to a wireless internet-connected laptop decreased motility and induced DNA fragmentation by a nonthermal effect. We speculate that keeping a laptop connected wirelessly to the internet on the lap near the testes may result in decreased male fertility. Further in vitro and in vivo studies are needed to prove this contention. (Fertil Steril® 2012;■:■–■. ©2012 by American Society for Reproductive Medicine.)
Key Words: Laptop computer, Wi-Fi, sperm quality, fertility, sperm DNA fragmentation

In recent years, the use of portable computers (laptops, connected to local area networks wirelessly, also known as Wi-Fi) has increased dramatically. Laptops have become indispensable devices in our daily life, offering flexibility and mobility to users. People using Wi-Fi may be exposed to radio signals absorbing some of the transmitted energy in their bodies. Portable computers are commonly used on the lap (1–3), therefore exposing the genital area to radio frequency electromagnetic waves (RF-EMW) as well as high temperatures (3, 4).

Infertility is a common worldwide condition that affects more than 70 million couples of reproductive age (5). It has been suggested that male fertility has declined during the past several decades (6). Such decline has been attributed to the direct or indirect exposure to certain environmental factors such as RF-EMW (7).

Extremely low frequency magnetic fields can initiate a number of biochemical and physiological alterations in biological systems of different species (8–12). Many of these effects have been associated with free-radical production (13, 14). Free radicals are causative factors of oxidative damage of cellular structures and molecules such as lipids, proteins, and nucleic acids. Free radicals react with polyunsaturated fatty acids in cell membranes promoting a process called lipid peroxidation. In human spermatozoa the presence of unesterified polyunsaturated fatty acids is causally associated with the induction of reactive oxygen species (ROS) generation and lipid peroxidation (15). Damage may occur at the membrane level, leading to immotility and cell death, or at the DNA level. DNA integrity is essential to normal conception. Sperm DNA fragmentation has been associated with impaired fertilization, poor embryonic development, high rates of miscarriage, and increased incidence of morbidity in the offspring, including childhood cancer (16, 17). It has been proposed that genetic and

Received June 14, 2011; revised September 9, 2011; accepted October 11, 2011.
C.A. has nothing to disclose. A.M. has nothing to disclose. C.A.S.S. has nothing to disclose. G.F.D. has nothing to disclose.
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Fertility and Sterility® Vol. ■, No. ■, ■ 2012 0015-0282/$36.00

doi:10.1016/j.fertnstert.2011.10.012

SCIENTIFIC REPORTS

OPEN

SUBJECT AREAS:
DEVELOPMENT OF THE NERVOUS SYSTEM
PATTERN FORMATION
BIOPHYSICS
ANIMAL BEHAVIOUR

Received
13 July 2011

Accepted
17 February 2012

Published
15 March 2012

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Fetal Radiofrequency Radiation Exposure From 800-1900 Mhz-Rated Cellular Telephones Affects Neurodevelopment and Behavior in Mice

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Neurobehavioral disorders are increasingly prevalent in children, however their etiology is not well understood. An association between prenatal cellular telephone use and hyperactivity in children has been postulated, yet the direct effects of radiofrequency radiation exposure on neurodevelopment remain unknown. Here we used a mouse model to demonstrate that *in-utero* radiofrequency exposure from cellular telephones does affect adult behavior. Mice exposed *in-utero* were hyperactive and had impaired memory as determined using the object recognition, light/dark box and step-down assays. Whole cell patch clamp recordings of miniature excitatory postsynaptic currents (mEPSCs) revealed that these behavioral changes were due to altered neuronal developmental programming. Exposed mice had dose-responsive impaired glutamatergic synaptic transmission onto layer V pyramidal neurons of the prefrontal cortex. We present the first experimental evidence of neuropathology due to *in-utero* cellular telephone radiation. Further experiments are needed in humans or non-human primates to determine the risk of exposure during pregnancy.

To date, 3–7% of school-aged children suffer from attention deficit hyperactivity disorder (ADHD)[1]. Children diagnosed with ADHD are at greater risk for low academic achievement, poor school performance, and delinquent behavior inconsistent with their developmental level[2,3]. The diagnosis of ADHD has increased at an average rate of 3% per year since 1997, making the condition a growing public health concern[1]. The behavioral problems in ADHD have been associated with neuropathology localized primarily to the prefrontal cortex. Children with ADHD have a reduction in prefrontal cortex volume, a reduction in gray and white matter, and asymmetry[4,5]. These children also have a deficit in working memory associated with inattention and controlled by activity of neurons in the prefrontal cortex[6]. A recent study showed that poor attention and low working memory capacity may be due to the inability to override the involuntary capture of attention by irrelevant information[7]. This too is controlled by the prefrontal cortex, as the shifting of one's attention voluntarily is driven by "top-down" signals in the prefrontal cortex while the involuntary capture of attention depends on "bottom-up" signals from both subcortical structures and the visual cortex[7].

The etiology of ADHD remains unknown and growing evidence suggests that it is not solely due to genetic factors[8]. Risk factors include family psychiatric history, socioeconomic status, gender, and smoking during pregnancy[9,10]. A recent epidemiologic study found an association between prenatal cellular telephone exposure and subsequent behavioral problems in the exposed offspring[11]. This association is important given the increasing number of cellular phone users worldwide, reaching approximately four billion as of December 2008[12]. However, evidence of direct causation is lacking.

The specific absorption rate (SAR) is a measure of tissue radiation exposure. The European Union has set a SAR limit of 2.0 W/kg and in the United States this limit is set at 1.6 W/kg[13]. The *in-utero* effects of radiation exposure

Journal of Pediatric Urology (2012) xx, 1–7

Journal of Pediatric urology

Immunohistopathologic demonstration of deleterious effects on growing rat testes of radiofrequency waves emitted from conventional Wi-Fi devices

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Received 2 October 2011; accepted 28 February 2012

KEYWORDS
Carcinogenesis tests;
Infertility;
Internet;
Oxidative stress;
Wireless technology;
Testes

Abstract *Objective:* To investigate effects on rat testes of radiofrequency radiation emitted from indoor Wi-Fi Internet access devices using 802.11.g wireless standards.
Methods: Ten Wistar albino male rats were divided into experimental and control groups, with five rats per group. Standard wireless gateways communicating at 2.437 GHz were used as radiofrequency wave sources. The experimental group was exposed to radiofrequency energy for 24 h a day for 20 weeks. The rats were sacrificed at the end of the study. Intracardiac blood was sampled for serum 8-hydroxy-2′-deoxyguanosine levels. Testes were removed and examined histologically and immunohistochemically. Testis tissues were analyzed for malondialdehyde levels and prooxidant–antioxidant enzyme activities.
Results: We observed significant increases in serum 8-hydroxy-2′-deoxyguanosine levels and 8-hydroxyguanosine staining in the testes of the experimental group indicating DNA damage due to exposure ($p < 0.05$). We also found decreased levels of catalase and glutathione peroxidase activity in the experimental group, which may have been due to radiofrequency effects on enzyme activity ($p < 0.05$).

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doi:10.1016/j.jpurol.2012.02.015

Journal of Chemical Neuroanatomy 75 (2016) 105–110

Contents lists available at ScienceDirect

Journal of Chemical Neuroanatomy

journal homepage: www.elsevier.com/locate/jchemneu

Maternal exposure to a continuous 900-MHz electromagnetic field provokes neuronal loss and pathological changes in cerebellum of 32-day-old female rat offspring

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ARTICLE INFO

Article history:
Received 17 May 2015
Received in revised form 8 September 2015
Accepted 9 September 2015
Available online 21 September 2015

Keywords:
Electromagnetic field
Female rat
Cerebellum
Purkinje cell
Stereology

ABSTRACT

Large numbers of people are unknowingly exposed to electromagnetic fields (EMF) from wireless devices. Evidence exists for altered cerebellar development in association with prenatal exposure to EMF. However, insufficient information is still available regarding the effects of exposure to 900 megahertz (MHz) EMF during the prenatal period on subsequent postnatal cerebellar development. This study was planned to investigate the 32-day-old female rat pup cerebellum following exposure to 900 MHz EMF during the prenatal period using stereological and histopathological evaluation methods. Pregnant rats were divided into control, sham and EMF groups. Pregnant EMF group (PEMFG) rats were exposed to 900 MHz EMF for 1 h inside an EMF cage during days 13–21 of pregnancy. Pregnant sham group (PSG) rats were also placed inside the EMF cage during days 13–21 of pregnancy for 1 h, but were not exposed to any EMF. No procedure was performed on the pregnant control group (PCG) rats. Newborn control group (CG) rats were obtained from the PCG mothers, newborn sham group (SG) rats from the PSG and newborn EMF group (EMFG) rats from the PEMFG rats. The cerebellums of the newborn female rats were extracted on postnatal day 32. The number of Purkinje cells was estimated stereologically, and histopathological evaluations were also performed on cerebellar sections. Total Purkinje cell numbers calculated using stereological analysis were significantly lower in EMFG compared to CG ($p < 0.05$) and SG ($p < 0.05$). Additionally, some pathological changes such as pyknotic neurons with dark cytoplasm were observed in EMFG sections under light microscopy. In conclusion, our study results show that prenatal exposure to EMF affects the development of Purkinje cells in the female rat cerebellum and that the consequences of this pathological effect persist after the postnatal period.

1. Introduction

According to the International Telecommunication Union, the number of mobile cellular subscriptions worldwide is almost the same as that of the total world population. The number of mobile cellular subscriptions at the end of 2104 was almost 7 billion, representing a penetration rate of 96% (ITU, 2014). This means that thousands of people are exposed to electromagnetic fields (EMF) of varying strengths from wireless devices (i.e. cell phones and cordless phones, cellular antennas and towers, and broadcast transmission towers), unwillingly and mostly unawares (Fragopoulou et al., 2010; Hardell and Sage, 2008).

The normal morphology and functioning of the neuronal system (NS) is connected with the prenatal and postnatal development of cerebellar cortex major neurons such as Purkinje cells. The developing NS is known to be vulnerable to potentially harmful factors such as chemical agents, environmental factors, drugs (Odaci et al., 2004; Ragbetli et al., 2007) and EMF exposure,

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http://dx.doi.org/10.1016/j.jchemneu.2015.09.002
0891-0618/

INTERNATIONAL JOURNAL OF RADIATION BIOLOGY, 2016
http://dx.doi.org/10.3109/09553002.2016.1135262

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RESEARCH ARTICLE

Immune responses of a wall lizard to whole-body exposure to radiofrequency electromagnetic radiation

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ABSTRACT

Purpose During the last three decades, the number of devices that emit non-ionizing electromagnetic radiation (EMR) at the wireless communication spectrum has rapidly increased and possible effects on living organisms have become a major concern. The purpose of this study was to investigate the effects of radiofrequency EMR emitted by a widely used wireless communication device, namely the Digital Enhanced Communication Telephony (DECT) base, on the immune responses of the Aegean wall lizard (*Podarcis erhardii*).

Materials and methods Adult male lizards were exposed 24 h/day for 8 weeks to 1880–1900 MHz DECT base radiation at average electric field intensity of 3.2 V/m. Immune reactivity was assessed using the phytohemagglutinin (PHA) skin swelling and mixed lymphocyte reaction (MLR) tests.

Results Our results revealed a noticeable suppression (approximately 45%) of inflammatory responses in EMR-exposed lizards compared to sham-exposed animals. T cell-mediated responses were marginally affected.

Conclusion Daily radiofrequency EMR exposure seems to affect, at least partially, the immunocompetence of the Aegean wall lizard.

ARTICLE HISTORY
Received 17 August 2015
Revised 25 November 2015
Accepted 30 November 2015

KEYWORDS
Non-ionizing radiation; inflammation; skin; immunology; reptiles

Introduction

The continuous increase of wireless telecommunication sources, such as mobile phones, cordless phones, wireless fidelity (Wi-Fi) routers, base and frequency modulation (FM) stations, has led to a dramatic increase in environmental levels of radiofrequency electromagnetic radiation (RF-EMR) (Ahlbom and Feychting 2003, Margaritis et al. 2014). These RF-EMR sources emit radiation in a wide spectrum of frequencies (90 MHz – 2500 MHz), with different characteristics regarding their modulation, intensity and energy. The energy of this type of radiation is weak compared to ionizing radiation. Still, it can affect humans and the wildlife (Balmori 2009, Kesari et al. 2013, Singh et al. 2014), even at average electric field intensity values far below International Commission on Non-Ionizing Radiation Protection (ICNIRP 1998) standards, supporting, thus, the notion of RF-EMR non-thermal effects on biological systems (Fragopoulou et al. 2010a, Giuliani and Soffritti 2010).

Recent research provides strong evidence that RF-EMR largely affects critical biological processes and leads to oxidative stress, cell death, nervous system dysfunctions and carcinogenesis (Fragopoulou et al. 2010b, 2012, Sonmez et al. 2010, Kesari et al. 2013, Manta et al. 2014). Such consequences have deleterious effect on wildlife and may contribute to the decline of animal populations (Magras and Xenos 1997, Balmori 2010, Margaritis et al. 2014). However, the potential effects of RF-EMR are still controversial and debated (Miyakoshi 2013). Hence, there is an imperative need for better understanding EMR effects on the processes and mechanisms that are related to the survival of animals, among which the resistance to pathogens and diseases stands out (Ahlbom and Feychting 2003).

To counteract the consequences of pathogens' activity and infectious diseases, vertebrates evolved efficient immune responses, comprising a plethora of non-specific and specific mechanisms (Altizer et al. 2003). New insights into the function of the immune system under non-ionizing EMR exposure demonstrated that electromagnetic fields (EMF) might cause immune dysregulation in humans and the wildlife. Indeed, EMR can alter natural killer cell and macrophage activity and thus, may cause the deviation of inflammatory processes (Rao et al. 1983, Smialowicz et al. 1983, Boscolo et al. 2001, Vianale et al. 2008), trigger oxidative stress affecting susceptibility to diseases (Fernie and Bird 2001, Aydin and Akar 2011), promote cancer development (Repacholi et al. 1997, French et al. 2001), and modify the functional capacity and adhesion ability of

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Journal of Toxicology and Environmental Health, Part A, 78:353–356, 2015

ISSN: 1528-7394 print / 1087-2620 online
DOI: 10.1080/15287394.2014.979272

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STRUCTURAL AND ULTRASTRUCTURAL STUDY OF RAT LIVER INFLUENCED BY ELECTROMAGNETIC RADIATION

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Mobile communication systems are undoubtedly an environmental source of electromagnetic radiation (EMR). There is an increasing concern regarding the interactions of EMR with the humans. The aim of this study was to examine the effects of EMR on Wistar rat liver. Mature rats were exposed to electromagnetic field of frequency 2.45 GHz and mean power density of 2.8 mW/cm^2 for 3 h/d for 3 wk. Samples of the liver were obtained 3 h after the last irradiation and processed histologically for light and transmission electron microscopy. Data demonstrated the presence of moderate hyperemia, dilatation of liver sinusoids, and small inflammatory foci in the center of liver lobules. Structure of hepatocytes was not altered and all described changes were classified as moderate. Electron microscopy of hepatocytes revealed vesicles of different sizes and shapes, lipid droplets, and proliferation of smooth endoplasmic reticulum. Occasionally necrotizing hepatocytes were observed. Our observations demonstrate that EMR exposure produced adverse effects on rat liver.

Electromagnetic radiation (EMR) is one of the most significant environmental factors and has been a subject of intensive studies attributed to deployment of wireless communications and consequent exposure to radiation (Hossmann and Hermann, 2003). EMR in the range of 100 kHz–300 GHz is becoming more widespread and extensively employed in both the urban and rural environment, attributed to increasing use of radio and TV appliances, of radar units, and especially of mobile phones and wireless communication devices (Valberg et al., 2007). EMR was shown to induce damage in different organs, including the reproductive system, heart, lungs, kidney, testes, and liver (Fernie and Reynolds, 2005; Hanafy et al., 2010; Qin et al, 2012; Shahrbanoo et al., 2013; Almášiová et al., 2014), and affected negatively the motility of spermatozoa (Lukac et al., 2011). The aim of this study was to determine the potential adverse effects of EMR on the structure and ultrastructure of rat liver.

MATERIAL AND METHODS

Experimental Design and Animal Handling

The study was conducted on 40 male Wister rats, which were randomly divided into 2 groups: control ($n = 20$) and experimental ($n = 20$). Animals were maintained in cages at the controlled temperature of 21 ± 1°C, and had ad libitum access to water and food (Larsen diet). Rats were exposed to a pulsed-wave electromagnetic frequency (EMF) of 2.45 GHz at mean power density 2.8 mW/cm^2 in purpose-designed chamber

Received 15 October 2014; accepted 17 October 2014.
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Color versions of one or more of the figures in the article can be found online at www.tandfonline.com/uteh

Eur Arch Otorhinolaryngol
DOI 10.1007/s00405-013-2425-0

LARYNGOLOGY

Modulation of wireless (2.45 GHz)-induced oxidative toxicity in laryngotracheal mucosa of rat by melatonin

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Received: 21 January 2013 / Accepted: 27 February 2013

Abstract It is well known that oxidative stress induces larynx cancer, although antioxidants induce modulator role on etiology of the cancer. It is well known that electromagnetic radiation (EMR) induces oxidative stress in different cell systems. The aim of this study was to investigate the possible protective role of melatonin on oxidative stress induced by Wi-Fi (2.45 GHz) EMR in laryngotracheal mucosa of rat. For this purpose, 32 male rats were equally categorized into four groups, namely controls, sham controls, EMR-exposed rats, EMR-exposed rats treated with melatonin at a dose of 10 mg/kg/day. Except for the controls and sham controls, the animals were exposed to 2.45 GHz radiation during 60 min/day for 28 days. The lipid peroxidation levels were significantly ($p < 0.05$) higher in the radiation-exposed groups than in the control and sham control groups. The lipid peroxidation level in the irradiated animals treated with melatonin was significantly ($p < 0.01$) lower than in those that were only exposed to Wi-Fi radiation. The activity of glutathione peroxidase was lower in the irradiated-only group relative to control and sham control groups but its activity was significantly ($p < 0.05$) increased in the groups treated with melatonin. The reduced glutathione levels in the mucosa of rat did not change in the four groups. There is an apparent protective effect of melatonin on the Wi-Fi-induced oxidative stress in the laryngotracheal mucosa of rats by inhibition of free radical formation and support of the glutathione peroxidase antioxidant system.

Keywords Melatonin · Larynx · Trachea · Oxidative stress · Wireless devices

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Introduction

Wireless devices usages in industrial, scientific, medical, military and domestic applications, with potential leakage, of such radiation into the environment have increased by leaps and bounds in past decade [1]. From being a luxury and limited to the wealthy, wireless devices especially near 2.45 GHz is indispensable in daily lives [2]. However, every technological advance and its overuse possess possible adverse effects [3].

Exposure to electromagnetic radiation (EMR) induces degenerative effects via two ways, namely directly or indirectly. Direct effects of EMR induce production of reactive oxygen species (ROS), including superoxide anion, hydrogen peroxide, and hydroxyl radicals. The ROS contribute to tissue and DNA damages [1]. Exposure to 2.45 GHz EMR causes an increase in lipid peroxidation levels and a decrease in the activity of enzymes that prevent or protect against lipid peroxidation in tissues [4, 5]. The human cells have nonenzymatic and enzymatic antioxidant systems against degenerative effects of ROS. Glutathione

Published online: 12 March 2013

Biol Trace Elem Res (2009) 132:153–163
DOI 10.1007/s12011-009-8372-3

Effects of Selenium and L-Carnitine on Oxidative Stress in Blood of Rat Induced by 2.45-GHz Radiation from Wireless Devices

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Received: 23 January 2009 / Accepted: 30 March 2009 /
Published online: 25 April 2009

Abstract The levels of blood lipid peroxidation, glutathione peroxidase, reduced glutathione, and vitamin C were used to follow the level of oxidative damage caused by 2.45 GHz electromagnetic radiation in rats. The possible protective effects of selenium and L-carnitine were also tested and compared to untreated controls. Thirty male Wistar Albino rats were equally divided into five groups, namely Groups A_1 and A_2: controls and sham controls, respectively; Group B: EMR; Group C: EMR + selenium, Group D: EMR + L-carnitine. Groups B–D were exposed to 2.45 GHz electromagnetic radiation during 60 min/day for 28 days. The lipid peroxidation levels in plasma and erythrocytes were significantly higher in group B than in groups A_1 and A_2 ($p<0.05$), although the reduced glutathione and glutathione peroxidase values were slightly lower in erythrocytes of group B compared to

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Provocation study using heart rate variability shows microwave radiation from 2.4 GHz cordless phone affects autonomic nervous system

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Abstract

Aim: **The effect of pulsed (100 Hz) microwave (MW) radiation on heart rate variability (HRV) was tested in a double blind study.** ***Materials and Methods:*** **Twenty-five subjects in Colorado between the ages of 37 to 79 completed an electrohypersensitivity (EHS) questionnaire. After recording their orthostatic HRV, we did continuous real-time monitoring of HRV in a provocation study, where supine subjects were exposed for 3-minute intervals to radiation generated by a cordless phone at 2.4 GHz or to sham exposure.** ***Results:*** **Questionnaire: Based on self-assessments, participants classified themselves as extremely electrically sensitive (24%), moderately (16%), slightly (16%), not sensitive (8%) or with no opinion (36%) about their sensitivity. The top 10 symptoms experienced by those claiming to be sensitive include memory problems, difficulty concentrating, eye problems, sleep disorder, feeling unwell, headache, dizziness, tinnitus, chronic fatigue, and heart palpitations. The five most common objects allegedly causing sensitivity were fluorescent lights, antennas, cell phones, Wi-Fi, and cordless phones. Provocation Experiment: Forty percent of the subjects experienced some changes in their HRV attributable to digitally pulsed (100 Hz) MW radiation. For some the response was extreme (tachycardia), for others moderate to mild (changes in sympathetic nervous system and/or parasympathetic nervous system). and for some there was no observable reaction either because of high adaptive capacity or because of systemic neurovegetative exhaustion.** ***Conclusions:*** **Orthostatic HRV combined with provocation testing may provide a diagnostic test for some EHS sufferers when they are exposed to electromagnetic emitting devices. This is the first study that documents immediate and dramatic changes in both Hearth Rate (HR) and HR variability (HRV) associated with MW exposure at levels**

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well below (0.5%) federal guidelines in Canada and the United States (1000 microW/cm^2).

***Key Words*: heart rate variability, microwave radiation, DECT phone, autonomic nervous system, provocation study, sympathetic, parasympathetic, cordless phone, 2.4 GHz, electrohypersensitivity**

Introduction

A growing population claims to be sensitive to devices emitting electromagnetic energy. Hallberg and Oberfeld[1] report a prevalence of electrohypersensitivity (EHS) that has increased from less than 2% prior to 1997 to approximately 10% by 2004 and is expected to affect 50% of the population by 2017. Whether this is due to a real increase in EHS or to greater media attention, is not known. However, to label EHS as a psychological disorder or to attribute the symptoms to aging and/or stress does not resolve the issue that a growing population, especially those under the age of 60, are suffering from some combination of fatigue, sleep disturbance, chronic pain, skin, eye, hearing, cardiovascular and balance problems, mood disorders as well as cognitive dysfunction and that these symptoms appear to worsen when people are exposed to electromagnetic emitting devices[2-7].

The World Health Organization (WHO) organized an international seminar and working group meeting in Prague on EMF Hypersensitivity in 2004, and at that meeting they defined EHS as follows[8]:

". . . a phenomenon where individuals experience adverse health effects while using or being in the vicinity of devices emanating electric, magnetic, or electromagnetic fields (EMFs) . . . Whatever its cause, EHS is a real and sometimes a debilitating problem for the affected persons . . . Their exposures are generally several orders of magnitude under the limits in internationally accepted standards."

The WHO goes on to state that:

"EHS is characterized by a variety of non-specific symptoms, which afflicted individuals attribute to exposure to EMF. The symptoms most commonly experienced include dermatological symptoms (redness, tingling, and burning sensations) as well as neurasthenic and vegetative symptoms (fatigue, tiredness, concentration difficulties, dizziness, nausea, heart palpitation and digestive disturbances). The collection of symptoms is not part of any recognized syndrome."

Both provocation studies (where individuals are exposed to some form of electromagnetic energy and their symptoms are documented) and amelioration studies (where exposure is reduced) can shed light on the offending energy source and the type and rate of reaction.

Several amelioration studies have documented improvements in the behavior of students and the health and wellbeing of teachers[9], among asthmatics[10], and in both diabetics and those with multiple sclerosis[11,12] when their exposure to dirty electricity is reduced. Dirty electricity refers to microsurges flowing along electrical wires in the kHz

Electromagnetic Biology and Medicine, June 2013; 32(2): 253–266

ISSN 1536-8378 print/ISSN 1536-8386 online
DOI: 10.3109/15368378.2013.776437

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Replication of heart rate variability provocation study with 2.4-GHz cordless phone confirms original findings

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This is a replication of a study that we previously conducted in Colorado with 25 subjects designed to test the effect of electromagnetic radiation generated by the base station of a cordless phone on heart rate variability (HRV). In this study, we analyzed the response of 69 subjects between the ages of 26 and 80 in both Canada and the USA. Subjects were exposed to radiation for 3-min intervals generated by a 2.4-GHz cordless phone base station (3–8 $\mu W/cm^2$). A few participants had a severe reaction to the radiation with an increase in heart rate and altered HRV indicative of an alarm response to stress. Based on the HRV analyses of the 69 subjects, 7% were classified as being "moderately to very" sensitive, 29% were "little to moderately" sensitive, 30% were "not to little" sensitive and 6% were "unknown". These results are not psychosomatic and are not due to electromagnetic interference. Twenty-five percent of the subjects' self-proclaimed sensitivity corresponded to that based on the HRV analysis, while 32% overestimated their sensitivity and 42% did not know whether or not they were electrically sensitive. Of the 39 participants who claimed to experience some electrical hypersensitivity, 36% claimed they also reacted to a cordless phone and experienced heart symptoms and, of these, 64% were classified as having some degree of electrohypersensitivity (EHS) based on their HRV response. Novel findings include documentation of a delayed response to radiation. Orthostatic HRV testing combined with provocation testing may provide a diagnostic tool for some sufferers of EHS when they are exposed to electromagnetic emitting devices. The protocol used underestimates reaction to electromagnetic radiation for those who have a delayed autonomic nervous system reaction and it may under diagnose those who have adrenal exhaustion as their ability to mount a response to a stressor is diminished.

Keywords: heart rate variability, mobile phone, tachycardia, arrhythmia, microwave radiation, radio frequency radiation, electrohypersensitivity, autonomic nervous system

Introduction

Individuals who complain of electrical hypersensitivity experience a myriad of symptoms that may include heart palpitation, arrhythmia, tachycardia, pain or pressure in the chest that may or may not be accompanied by anxiety, dizziness, nausea and headaches (Austrian Medical Association, 2012; Bevington, 2010; McCarty et al., 2011; Eltiti et al., 2007; Johansson, 2006). Since we have technology to measure the activity of

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WI-FI ELECTROMAGNETIC FIELDS EXERT GENDER RELATED ALTERATIONS ON EEG

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Abstract

The present study investigated the influence of electromagnetic fields, similar to that emitted by Wi-Fi system, on brain activity. Fifteen female and fifteen male subjects performed a short memory task (Wechsler test), both without and with exposure to a 2.4GHz Wi-Fi signal. For each subject, radiation condition and electrode, the amplitude in the frequency domain of the EEG signal was calculated from the recordings of 30 scalp electrodes, using the Fourier transform.

The presence of radiation had no effect on the energies of alpha and beta band of male subjects, while it reduced these energies of female subjects, resulting in significantly lower energies, as compared to those of males.

Delta and theta band energies did not experience any noteworthy effect from gender, radiation condition and their interaction. Conversely, there was a significant interaction effect (gender x radiation) on the energies of alpha and beta rhythms.

Interestingly, this pattern was observed for a number of electrodes, which formed two distinct clusters: one located at right- anterior and the second at occipital brain areas.

The present data support the idea that Wi-Fi signal may influence normal physiology through changes in gender related cortical excitability, as reflected by alpha and beta EEG frequencies.

ELECTROMAGNETIC BIOLOGY AND MEDICINE

http://informahealthcare.com/ebm
ISSN: 1536-8378 (print), 1536-8386 (electronic)

Electromagn Biol Med, Early Online: 1–25
 DOI: 10.3109/15368378.2013.800102

informa healthcare

ORIGINAL ARTICLE

Drosophila oogenesis as a bio-marker responding to EMF sources

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Abstract

The model biological organisms *Drosophila melanogaster* and *Drosophila virilis* have been utilized to assess effects on apoptotic cell death of follicles during oogenesis and reproductive capacity (fecundity) decline. A total of 280 different experiments were performed using newly emerged flies exposed for short time daily for 3–7 d to various EMF sources including: GSM 900/1800 MHz mobile phone, 1880–1900 MHz DECT wireless base, DECT wireless handset, mobile phone-DECT handset combination, 2.44 GHz wireless network (Wi-Fi), 2.44 GHz blue tooth, 92.8 MHz FM generator, 27.15 MHz baby monitor, 900 MHz CW RF generator and microwave oven's 2.44 GHz RF and magnetic field components. Mobile phone was used as a reference exposure system for evaluating factors considered very important in dosimetry extending our published work with *D. melanogaster* to the insect *D. virilis*. Distance from the emitting source, the exposure duration and the repeatability were examined. All EMF sources used created statistically significant effects regarding fecundity and cell death-apoptosis induction, even at very low intensity levels (0.3 V/m blue tooth radiation), well below ICNIRP's guidelines, suggesting that Drosophila oogenesis system is suitable to be used as a biomarker for exploring potential EMF bioactivity. Also, there is no linear cumulative effect when increasing the duration of exposure or using one EMF source after the other (i.e. mobile phone and DECT handset) at the specific conditions used. The role of the average versus the peak E-field values as measured by spectrum analyzers on the final effects is discussed.

Keywords

Apoptosis, baby monitor, blue tooth, DECT base, DECT handset, Drosophila, EMFs, mobile phones, MW oven, reproduction, Wi-Fi

History

Received 31 August 2012
Revised 2 March 2013
Accepted 7 April 2013
Published online 31 July 2013

Introduction

Wireless communication devices are widely used worldwide at nearly all human activities at home, for entertainment, for education and especially at work. The related devices include the well-known cell phones (nearly 6 billion users globally), the wireless DECT telephones (no records available but apparently their number is considered very high), the wireless local area network routers (no records available), iPads which are increasingly penetrating the market having only Wi-Fi (and not wired) internet access, not to mention the baby monitors and the also newly developed "smart meters". Apart from the above "electromagnetic pollution" sources, there is also direct or indirect radiation exposure of humans by FM and TV broadcast stations, cell phone network mast stations, TETRA police and fire department antennae and many more. Because people may be adversely affected by the environmental impact of such electromagnetic fields (EMFs), it is of great scientific and social interest to explore the possible health hazards (Behari, 2010) potentially caused by this radiation spectrum. Major research is associated mainly with cell phones, while at the same time the other sources have been neglected with the exception of the epidemiological and partially clinical studies involving DECT phones (Hardell & Carlberg, 2009; Hardell et al., 2004, 2006, 2011; Khurana et al., 2010). Mobile phone-like radiation studies have been performed during the last decades investigating a variety of biological effects, in humans with clinical studies and experimental work with rodents, flies and cell cultures. Assessing the possible link between exposure to electromagnetic fields and genotoxic effects, a number of studies have reported DNA damage, cell malformations, apoptotic cell death, changes in chromatin conformation and micronucleus formation in different cell types or organisms (Lai & Singh, 1996; Lixia et al., 2006; Ruediger, 2009; Zhao et al., 2007). However, in other studies, no genotoxic effects from exposure to EMF were observed (Belyaev et al., 2006; Verschaeve, 2005).

Mobile phone radiation has been also found to cause broad changes in gene and protein expression in certain cell types (Belyaev et al., 2006; Nylund & Leszczynski, 2006; Nylund et al., 2009; Remondini et al., 2006). Our group using

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Int. J. Radiat. Biol., Vol. 85, No. 8, August 2009, pp. 680–689

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Modulator effects of L-carnitine and selenium on wireless devices (2.45 GHz)-induced oxidative stress and electroencephalography records in brain of rat

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(Received 8 September 2008; Revised 25 April 2009; Accepted 29 April 2009)

Abstract

Purpose: Electromagnetic radiation (EMR) from wireless devices may affect biological systems by increasing free radicals. The present study was designed to determine the effects of 2.45 GHz EMR on the brain antioxidant redox system and electroencephalography (EEG) records in rat. The possible protective effects of selenium and L-carnitine were also tested and compared to untreated controls.

Materials and methods: Thirty rats were equally divided into five different groups, namely Group A_1: Cage control, Group A_2: Sham control, group B: 2.45 GHz EMR, group C: 2.45 GHz EMR + selenium, group D: 2.45 GHz EMR + L-carnitine. Groups B, C and D were exposed to 2.45 GHz EMR during 60 min/day for 28 days. End of the experiments, EEG records and the brain cortex samples were taken.

Results: The cortex brain vitamin A ($p < 0.05$), vitamin C ($p < 0.01$) and vitamin E ($p < 0.05$) concentrations values were lower in group B than in group A1 and A2 although their concentrations were increased by selenium and L-carnitine supplementation. Lipid peroxidation, levels were lower in group C ($p < 0.05$) and D ($p < 0.01$) than in group B where as reduced glutathione levels were higher in group C ($p < 0.05$) than in group A1, A2 and B. However, B-carotene levels did not change in the five groups.

Conclusions: L-carnitine and selenium seem to have protective effects on the 2.45 GHz-induced decrease of the vitamins by supporting antioxidant redox system. L-carnitine on the vitamin concentrations seems to more protective affect than in selenium.

Keywords: *Wireless devices, lipid peroxidation, brain, vitamin E, L-carnitine, selenium, electroencephalography records*

Abbreviations: ANOVA, analysis of variance; EEG, electroencephalography; EMF, electromagnetic fields; EMR, electromagnetic radiation; GSH, glutathione; GSH-Px, glutathione peroxidase; L-CAR, L-carnitine; LP, lipid peroxidation; LSD, least significance test; ROS, reactive oxygen species; SAR, specific absorption rate; SD, standard deviation; Se, selenium

Introduction

In present times there is widespread use of 2.45 GHz irradiation-emitting devices in industrial, scientific, medical, military and domestic applications, with potential leakage of such radiation into the environment (Crouzier et al. 2007). Several studies have suggested that biological systems might be sensitive to such form of radiation (Koyu et al. 2005, Köylü et al. 2006). Today there is widespread use of 2.45 GHz radiation from common household devices likemicrowave ovens, wireless access points, and computers, which in some cases were shown to be carcinogenic (Omura and Losco 1993).

Reactive oxygen substances (ROS) are produced by a free radical chain reaction, which can also be initiated by ROS (Nazıroğlu 2007a). The ROS, i.e. singlet oxygen, superoxide anion radical and hydroxyl radical, contribute to tissue damage (Nazıroğlu 2007b). ROS also cause injury by reacting with biomolecules such as lipids, proteins and nucleic acids as well as by depleting enzymatic and/or non-enzymatic antioxidants in the brain (Halliwell 2006, Nazıroğlu et al. 2008). Memory and learning

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ISSN 0955-3002 print/ISSN 1362-3095 online
DOI: 10.1080/09553000903009530

International Journal of Radiation Biology, June 2012; 88(6): 449–456

ISSN 0955-3002 print / ISSN 1362-3095 online
DOI: 10.3109/09553002.2012.682192

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healthcare

2.45-Gz wireless devices induce oxidative stress and proliferation through cytosolic Ca^{2+} influx in human leukemia cancer cells

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Abstract

Purpose: **Electromagnetic radiation from wireless devices may affect biological systems by increasing free radicals. The present study was designed to determine the effects of 2.45 GHz radiation on the antioxidant redox system, calcium ion signaling, cell count and viability in human leukemia 60 cells.**

Materials and methods: **Twelve cell cultures were equally divided into two main groups as controls ($n = 6$) and irradiated ($n = 6$) and then subdivided into four different subgroups depending on the duration of exposure, namely 1, 2, 12 and 24 hours. The samples were analyzed immediately after the experimental period.**

Results: **The extent of lipid peroxidation, cytosolic free Ca^{2+} and cell numbers were higher in 2.45 GHz groups than in the controls. The increase of cytosolic free Ca^{2+} concentrations was radiation time-dependent and was highest at 24-h exposure. The reduced glutathione, glutathione peroxidase, vitamin C and cell viability values did not show any changes in any of the experimental groups. 2-aminoethyl diphenylborinate inhibits Ca^{2+} ions influx by blockage of the transient receptor potential melastatin 2.**

Conclusions: **2.45 GHz electromagnetic radiation appears to induce proliferative effects through oxidative stress and Ca^{2+} influx although blocking of transient receptor potential melastatin 2 channels by 2-aminoethyl diphenylborinate seems to counteract the effects on Ca^{2+} ions influx.**

Keywords: Wireless devices, oxidative stress, Ca^{2+} influx, TRPM2 channels, blood cancer

Introduction

In present times there is widespread use of 2.45 GHz irradiation-emitting devices in industrial, scientific, medical, military and domestic applications, with potential leakage of such radiation into the environment (Crouzier et al. 2007). Common household devices like microwave ovens, wireless access points, and computers were in some cases shown to be carcinogenic (Omura and Losco 1993). Other studies have suggested that biological systems might be sensitive to such form of radiation (Nazıroğlu and Gümral 2009, Nazıroğlu et al. 2012, Gümral et al. 2009).

Reactive oxygen species (ROS) are produced by a free radical chain reaction, which in some cases can be auto-initiated (Nazıroğlu 2007a, 2007b). These species cause injury by reacting with lipids, proteins and nucleic acids as well as by depleting antioxidants in cancer cells (Reuter et al. 2010). There are various antioxidant mechanisms in cells that neutralize the harmful effects of ROS. In contrast, exposure to electromagnetic radiation (EMR) results in increases of ROS due to loss of efficiency of antioxidants mechanisms and alterations in mitochondrial electron transfer chain (Kovacic and Somanathan 2008).

Glutathione peroxidase is responsible for the reduction of hydro- and organic peroxides in the presence of reduced glutathione (Whanger 2001). Vitamin C is a free radical scavenger that also transforms vitamin E to its active form (Nazıroğlu 2007a). We recently reported that 2.45 GHz radiation induced oxidative stress in brain and blood cells of rats (Nazıroğlu and Gümral 2009, Gümral et al. 2009). However, whether 2.45 GHz EMR also induces oxidative stress in cancer cells is still unknown and deserves further study.The homeostasis of Ca^{2+} ions is one of the most important factors of cellular physiological function. It is involved in such diverse functions as cellular proliferation, apoptosis, induction of oxidative stress and physiological signal transductions (Putney 2009). The cytosolic free calcium ion concentration $[Ca^{2+}]_i$ is controlled by a number of membrane-bound ion channels located both in the plasma and intracellular membranes. Transient receptor potential (TRP) channels are a group of non-selective cation channels that play important functions in sensory neurons (Nazıroğlu 2011a). One subgroup of TRP melastatin is TRP melastatin 2 (TRPM2), which has two distinct domains with one functioning as an ion channel and the other as an adenosine diphosphate ribose-specific

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(Received 11 July 2011; revised 28 March 2012; accepted 30 March 2012)

Physiology & Behavior 105 (2012) 683–692

Contents lists available at SciVerse ScienceDirect

Physiology & Behavior

journal homepage: www.elsevier.com/locate/phb

Melatonin modulates wireless (2.45 GHz)-induced oxidative injury through TRPM2 and voltage gated Ca^{2+} channels in brain and dorsal root ganglion in rat

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ARTICLE INFO

Article history:
Received 9 August 2011
Received in revised form 4 October 2011
Accepted 5 October 2011

Keywords:
Melatonin
Ca^{2+} influx
Dorsal root ganglion neuron
Electroencephalography records
Oxidative stress
TRPM2 channels
Wireless devices

ABSTRACT

We aimed to investigate the protective effects of melatonin and 2.45 GHz electromagnetic radiation (EMR) on brain and dorsal root ganglion (DRG) neuron antioxidant redox system, Ca^{2+} influx, cell viability and electroencephalography (EEG) records in the rat. Thirty two rats were equally divided into four different groups namely group A1: Cage control, group A2: Sham control, group B: 2.45 GHz EMR, group C: 2.45 GHz EMR + melatonin. Groups B and C were exposed to 2.45 GHz EMR during 60 min/day for 30 days. End of the experiments, EEG records and the brain cortex and DRG samples were taken. Lipid peroxidation (LP), cell viability and cytosolic Ca^{2+} values in DRG neurons were higher in group B than in groups A1 and A2 although their concentrations were increased by melatonin, 2-aminoethyldiphenyl borinate (2-APB), diltiazem and verapamil supplementation. Spike numbers of EEG records in group C were lower than in group B. Brain cortex vitamin E concentration was higher in group C than in group B. In conclusion, Melatonin supplementation in DRG neurons and brain seems to have protective effects on the 2.45 GHz-induced increase Ca^{2+} influx, EEG records and cell viability of the hormone through TRPM2 and voltage gated Ca^{2+} channels.

1. Introduction

In present times there is widespread use of 2.45 GHz irradiation-emitting devices in industrial, scientific, medical, military and domestic applications, with potential leakage of such radiation into the environment [1]. Several studies have suggested that biological systems might be sensitive to such form of radiation [2,3]. Today there is widespread use of 2.45 GHz radiation from common household devices like microwave ovens, wireless access points, and computers, which in some cases were shown to be carcinogenic [4].

Reactive oxygen substances (ROS) are produced by a free radical chain reaction, which can also be initiated by ROS [5]. ROS also cause injury by reacting with biomolecules such as lipids, proteins and nucleic acids as well as by depleting enzymatic antioxidant such as glutathione peroxidase (GSH-Px) and/or nonenzymatic antioxidants such as reduced glutathione (GSH), vitamins A, C, E and β-carotene in the brain and neuronal cells [6]. Pain and brain diseases are impaired in individuals with brain and sensory neuron-related neurodegenerative diseases; this is believed to be, in part, the result of excessive production of ROS [7]. The brain and neurons consume the highest amount of oxygen in the human body [6] although most of the oxygen used in brain tissues is converted to CO_2 and water, small amounts of oxygen form ROS [5]. The existence of polyunsaturated fatty acids which are targets of the ROS in the brain makes this organ more sensitive to oxidative damage [8]. ROS may be involved in the action of cell phone-induced electromagnetic radiation (EMR) on biological systems [2,9–11].

Neuropathic pain states severely limit the quality of life. There are several types of sensory neurons in dorsal root ganglion (DRG) neurons with responsiveness to different kinds of external and internal stimuli. These stimuli such as nociceptive, thermal and mechanical activate different receptors and ion channels that are present in the nerve terminals at the sensory receptive fields. Their expression in selective subsets of DRG neurons determines the response profile of individual neurons to a given stimulus [12]. Ca^{2+} homeostasis is one of the most important factors of cellular physiological function. It

Abbreviations: 2-APB, 2-aminoethyldiphenyl borinate; DRG, dorsal root ganglion; EEG, electroencephalography; EMF, electromagnetic fields; EMR, electromagnetic radiation; FFA, flufenamic acid; GSH, glutathione; GSH-Px, glutathione peroxidase; LP, lipid peroxidation; ROS, reactive oxygen species; SAR, specific absorption rate.

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0031-9384/$ – see front matter © 2011 Elsevier Inc. All rights reserved.
doi:10.1016/j.physbeh.2011.10.005

available at www.sciencedirect.com

ScienceDirect

www.elsevier.com/locate/brainres

BRAIN RESEARCH

Research Report

900 MHz electromagnetic field exposure affects qualitative and quantitative features of hippocampal pyramidal cells in the adult female rat

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ARTICLE INFO

Article history:
Accepted 5 February 2009
Available online 20 February 2009

Keywords:
Electromagnetic field
Cornu ammonis
Stereology
Optical fractionator
Female rat
Pyramidal cell

ABSTRACT

The effects of electromagnetic fields (EMFs) emitted by mobile phones on humans hold special interest due to their use in close proximity to the brain. The current study investigated the number of pyramidal cells in the cornu ammonis (CA) of the 16-week-old female rat hippocampus following postnatal exposure to a 900 megahertz (MHz) EMF. In this study were three groups of 6 rats: control (Cont), sham exposed (Sham), and EMF exposed (EMF). EMF group rats were exposed to 900 MHz EMF (1 h/day for 28 days) in an exposure tube. Sham group was placed in the exposure tube but not exposed to EMF (1 h/day for 28 days). Cont group was not placed into the exposure tube nor were they exposed to EMF during the study period. In EMF group rats, the specific energy absorption rate (SAR) varied between 0.016 (whole body) and 2 W/kg (locally in the head). All of the rats were sacrificed at the end of the experiment and the number of pyramidal cells in the CA was estimated using the optical fractionator technique. Histopathological evaluations were made on sections of the CA region of the hippocampus. Results showed that postnatal EMF exposure caused a significant decrease of the pyramidal cell number in the CA of the EMF group ($P<0.05$). Additionally, cell loss can be seen in the CA region of EMF group even at qualitative observation. These results may encourage researchers to evaluate the chronic effects of 900 MHz EMF on teenagers' brains.

1. Introduction

Mobile phones have been available since the end of the 1980s and have become common in the general population in recent years. In several countries, more than 80% of the population uses mobile phones today (Feychting et al., 2005). This worldwide expansion of the use of mobile phones has made electromagnetic field (EMF) exposure ubiquitous in modern

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0006-8993/$ – see front matter © 2009 Elsevier B.V. All rights reserved.
doi:10.1016/j.brainres.2009.02.011

Toxicology and Industrial Health 2009; **25:** 377–384
http://tih.sagepub.com

Chronic prenatal exposure to the 900 megahertz electromagnetic field induces pyramidal cell loss in the hippocampus of newborn rats

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Widespread use of mobile phones which are a major source of electromagnetic fields might affect living organisms. However, there has been no investigation concerning prenatal exposure to electromagnetic fields or their roles in the development of the pyramidal cells of the cornu ammonis in postnatal life. Two groups of pregnant rats, a control group and an experimental group, that were exposed to an electromagnetic field were used. For obtaining electromagnetic field offspring, the pregnant rats were exposed to 900 megahertz electromagnetic fields during the 1–19th gestation days. There were no actions performed on the control group during the same period. The offspring rats were spontaneously delivered—control group ($n = 6$) and electromagnetic field group ($n = 6$). Offspring were sacrificed for stereological analyses at the end of the 4th week. Pyramidal cell number in rat cornu ammonis was estimated using the optical fractionator technique. It was found that 900 megahertz of electromagnetic field significantly reduced the total pyramidal cell number in the cornu ammonis of the electromagnetic field group ($P < 0.001$). Therefore, although its exact mechanism is not clear, it is suggested that pyramidal cell loss in the cornu ammonis could be due to the 900 megahertz electromagnetic field exposure in the prenatal period. *Toxicology and Industrial Health* 2009; **25**: 377–384.

Key words: *cornu ammonis; electromagnetic field; pyramidal cell; rat; stereology*

Introduction

Mobile communication has generated intense scientific interest since its exponential growth has been accompanied by a parallel increase in the density of electromagnetic fields (EMFs) (Dubreuil, *et al.*, 2002). The extensive worldwide use of mobile phones raises the question of their possible biological effects (Mausset, *et al.*, 2001). Among the many effects, EMFs influence the physiology and morphology of cells in various respects and through this may increase the risks of leukemia, breast cancers (Juutilainen and de Seze, 1998; Lacy-Hulbert, *et al.*, 1998; Caplan, *et al.*, 2000), and brain tumors (Erman, *et al.*, 2001; Auvinen, *et al.*, 2002). Additionally, it has been reported that they aggravate headaches (Frey, 1998; Hocking, 1998) and that they modify EEG results and sleep stages in humans (Mann and Roschke, 1996; Wagner, *et al.*, 1998; Borbely, *et al.*, 1999). In the Global System for Mobile telecommunications (GSM), most mobile

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10.1177/0748233709106442

First International Journal of Andrology
ANDROLOGIA

ORIGINAL ARTICLE

Protective effects of melatonin against oxidative injury in rat testis induced by wireless (2.45 GHz) devices

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Keywords
Melatonin—oxidative stress—rat—testis—wireless devices

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Accepted: September 27, 2012

doi: 10.1111/and.12044

Summary

Wireless devices have become part of everyday life and mostly located near reproductive organs while they are in use. The present study was designed to determine the possible protective effects of melatonin on oxidative stress–dependent testis injury induced by 2.45-GHz electromagnetic radiation (EMR). Thirty-two rats were equally divided into four different groups, namely cage control (A1), sham control (A2), 2.45-GHz EMR (B) and 2.45-GHz EMR+melatonin (C). Group B and C were exposed to 2.45-GHz EMR during 60 min day^{-1} for 30 days. Lipid peroxidation levels were higher in Group B than in Group A1 and A2. Melatonin treatment prevented the increase in the lipid peroxidation induced by EMR. Also reduced glutathione (GSH) and glutathione peroxidase (GSH-Px) levels in Group D were higher than that of exposure group. Vitamin A and E concentrations decreased in exposure group, and melatonin prevented the decrease in vitamin E levels. In conclusion, wireless (2.45 GHz) EMR caused oxidative damage in testis by increasing the levels of lipid peroxidation and decreasing in vitamin A and E levels. Melatonin supplementation prevented oxidative damage induced by EMR and also supported the antioxidant redox system in the testis.

Introduction

There is widespread use of 2.45-GHz irradiation emitting wireless devices in industrial, scientific, medical, military and domestic applications, in the recent century. Therefore, the leakage of irradiation into the environment is inevitable (Wang *et al.*, 2005; Crouzier *et al.*, 2007). Studies had already shown the effects of 2.45-GHz electromagnetic radiation on different body parts like nervous system, body weight, tissue morphology and histology, blood biochemical parameters, hormones, immune system and reproductive system (Aweda *et al.*, 2003; Hossmann & Hermann, 2003; Kim *et al.*, 2007; Nazıroğlu & Gümral, 2009; Kumar *et al.*, 2011a; Saygin *et al.*, 2011). There is a consequence that exposure to electromagnetic radiation (EMR) is with enhanced production of reactive oxygen species (ROS), including superoxide anion, hydrogen peroxide and hydroxyl radicals (Murphy *et al.*, 1993; Aweda *et al.*, 2003). These species and/or other free radicals may be involved in the interactions of EMR on biological systems, but the cellular and molecular mechanisms involved in this process are not totally clear (Kim & Rhee, 2004; Gumral *et al.*, 2009; Nazıroğlu & Gümral, 2009). Some studies showed exposure to 2.45-GHz EMR may cause an increase in lipid peroxidation levels and a decrease in antioxidant enzymes that prevent or protect against lipid peroxidation (LPO) in reproductive tissues of male rats (Kumar *et al.*, 2011b).

Melatonin (N-acetyl-5-methoxy-tryptamine) is synthesised mainly by the pineal gland and has been considered a potent antioxidant, even more potent than vitamin E, which detoxifies a variety of ROS in many pathophysiological states (Pieri *et al.*, 1994; Ekmekcioglu, 2006). The direct effects of melatonin on the male reproductive system and testosterone synthesis from Leydig cells have also been examined in studies on animals. Because melatonin binding sites have been detected in the reproductive system of different species, it seems reasonable to assume that melatonin exerts its actions not only as an antioxidant but also through direct interaction with the steroidogenic cells of the reproductive organs (Oner-Iyidogan *et al.*, 2001; Armagan *et al.*, 2006).

Journal of Integrative Neuroscience, Vol. 10, No. 2 (2011) 189–202

DOI: 10.1142/S0219635211002695

Imperial College Press
www.icpress.co.uk

EFFECTS OF WI-FI SIGNALS ON THE P300 COMPONENT OF EVENT-RELATED POTENTIALS DURING AN AUDITORY HAYLING TASK

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Received 25 September 2010
Accepted 7 February 2011

The P300 component of event-related potentials (ERPs) is believed to index attention and working memory (WM) operation of the brain. The present study focused on the possible gender-related effects of Wi-Fi (Wireless Fidelity) electromagnetic fields (EMF) on these processes. Fifteen male and fifteen female subjects, matched for age and education level, were investigated while performing a modified version of the Hayling Sentence Completion test adjusted to induce WM. ERPs were recorded at 30 scalp electrodes, both without and with the exposure to a Wi-Fi signal. P300 amplitude values at 18 electrodes were found to be significantly lower in the response inhibition condition than in the response initiation and baseline conditions. Independent of the above effect, within the response inhibition condition there was also a significant gender X radiation interaction effect manifested at 15 leads by decreased P300 amplitudes of males in comparison to female subjects only at the presence of EMF. In conclusion, the present findings suggest that Wi-Fi exposure may exert gender-related alterations on neural activity associated with the amount of attentional resources engaged during a linguistic test adjusted to induce WM.

Keywords: Wi-Fi; P300 ERP component; Hayling; gender; EMF.

1. Introduction

Concern of health effects due to EMF, specifically radiofrequency (RF) exposure is currently arising. Numerous studies have investigated the potential effects of EMF,

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Pathophysiology xxx (2009) xxx–xxx

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Electromagnetic fields stress living cells

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Received 30 January 2009; accepted 30 January 2009

Abstract

Electromagnetic fields (EMF), in both ELF (extremely low frequency) and radio frequency (RF) ranges, activate the cellular stress response, a protective mechanism that induces the expression of stress response genes, e.g., HSP70, and increased levels of stress proteins, e.g., hsp70. The 20 different stress protein families are evolutionarily conserved and act as 'chaperones' in the cell when they 'help' repair and refold damaged proteins and transport them across cell membranes. Induction of the stress response involves activation of DNA, and despite the large difference in energy between ELF and RF, the same cellular pathways respond in both frequency ranges. Specific DNA sequences on the promoter of the HSP70 stress gene are responsive to EMF, and studies with model biochemical systems suggest that EMF could interact directly with electrons in DNA. While low energy EMF interacts with DNA to induce the stress response, increasing EMF energy in the RF range can lead to breaks in DNA strands. It is clear that in order to protect living cells, EMF safety limits must be changed from the current thermal standard, based on energy, to one based on biological responses that occur long before the threshold for thermal changes.

Keywords: DNA; Biosynthesis; Electromagnetic fields; ELF; RF

1. Electromagnetic fields (EMF) alter protein synthesis

Until recently, genetic information stored in DNA was considered essentially invulnerable to change as it was passed on from parent to progeny. Mutations, such as those caused by cosmic radiation at the most energetic end of the EM spectrum, were thought to be relatively infrequent. The model of gene regulation was believed to be that the negatively charged DNA was tightly wrapped up in the nucleus with positively charged histones, and that most genes were 'turned off' most of the time. Of course, different regions of the DNA code are being read more or less all the time to replenish essential proteins that have broken down and those needed during cell division.

New insights into the structure and function of DNA have resulted from numerous, well-done laboratory studies. The demonstration that EMF induces gene expression and the synthesis of specific proteins [1,2] generated considerable controversy from power companies, government agencies, physicists, and most recently, cell phone companies. Physicists have insisted that the reported results were not possible because there was not enough energy in the power frequency range (ELF) to activate DNA. They were thinking solely of mechanical interaction with a large molecule and not of the large hydration energy tied up in protein and DNA structures that could be released by small changes in charge [3]. Of the biologists who accepted such results [4], most thought that the EMF interaction originated at, and was amplified by, the cell membrane and not with DNA.

It is now generally accepted that weak EMF in the power frequency range can activate DNA to synthesize proteins. An EMF reactive sequence in the DNA has been identified [5] and shown to be transferable to other gene promoters [6]. This DNA sequence acts as an EMF sensitive antenna

Abbreviations: EMF, electromagnetic fields; Hz, hertz; ELF, extremely low frequency; RF, radio frequency; MAPK, mitogen activated protein kinase; ERK1\2, extracellular signal regulated kinase; JNK, c-Jun-terminal kinase p38MAPK; SAPK, stress activated protein kinase; NADH, nicotinamide adenine dinucleotide dehydrogenase; ROS, reactive oxygen species.

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0928-4680/$ – see front matter © 2009 Published by Elsevier Ireland Ltd.
doi:10.1016/j.pathophys.2009.01.006

Please cite this article in press as: M. Blank, R. Goodman, Electromagnetic fields stress living cells, Pathophysiology (2009), doi:10.1016/j.pathophys.2009.01.006

SCIENTIFIC REPORTS

OPEN

SUBJECT AREAS:
NEURAL PROGENITORS
NEURAL STEM CELLS

Received
17 March 2014

Accepted
9 May 2014

Published
29 May 2014

Correspondence and requests for materials should be addressed to Z.Z. (lunazhou00@163.com)

Exposure to 1800 MHz radiofrequency radiation impairs neurite outgrowth of embryonic neural stem cells

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A radiofrequency electromagnetic field (RF-EMF) of 1800 MHz is widely used in mobile communications. However, the effects of RF-EMFs on cell biology are unclear. Embryonic neural stem cells (eNSCs) play a critical role in brain development. Thus, detecting the effects of RF-EMF on eNSCs is important for exploring the effects of RF-EMF on brain development. Here, we exposed eNSCs to 1800 MHz RF-EMF at specific absorption rate (SAR) values of 1, 2, and 4 W/kg for 1, 2, and 3 days. We found that 1800 MHz RF-EMF exposure did not influence eNSC apoptosis, proliferation, cell cycle or the mRNA expressions of related genes. RF-EMF exposure also did not alter the ratio of eNSC differentiated neurons and astrocytes. However, neurite outgrowth of eNSC differentiated neurons was inhibited after 4 W/kg RF-EMF exposure for 3 days. Additionally, the mRNA and protein expression of the proneural genes Ngn1 and NeuroD, which are crucial for neurite outgrowth, were decreased after RF-EMF exposure. The expression of their inhibitor Hes1 was upregulated by RF-EMF exposure. These results together suggested that 1800 MHz RF-EMF exposure impairs neurite outgrowth of eNSCs. More attention should be given to the potential adverse effects of RF-EMF exposure on brain development.

The worldwide use of mobile phones has rapidly increased over the past decade, which has raised concerns about possible adverse health effects. The electromagnetic fields (EMFs) emitted from cellular phones ranges from 800 to 2000 MHz, which falls in the radiofrequency (RF) spectrum. The Global System for Mobile Communications (GSM) 1800 MHz RF-EMF is one of the most widely used frequencies. However, the biological effects of 1800 MHz RF-EMF on mammalian cells are largely unknown. The brain is a main concern with regards to the effects of RF-EMF because the brain is particularly sensitive to toxic chemicals and physical stimuli, especially during development. Previous studies have reported the potential effects of RF-EMF exposure on cell proliferation, apoptosis, and neuronal loss in the brain[1–3]. The underlying mechanisms may be due to increased ROS production, impaired mitochondrial functions, disruption of intracellular calcium homeostasis, upregulated heat shock protein expression, and finally, specific gene expression changes in the brain[4–8]. However, the available evidence is not sufficient to draw any definite conclusions, and future investigations still need to fully explore the detailed mechanisms. Epidemiologic and laboratory animal studies have also reported that irradiation of mobile phone frequency EMFs causes neurobehavioral dysfunction, impairs hippocampal neuronal plasticity, and increases the permeability of the blood-brain barrier and the risk of neurodegenerative diseases and brain tumours[9–12]. However, the effects of RF-EMF exposure on brain development remain largely unknown.

To date, the vast majority of mechanistic information regarding the effects of EMFs on brains have been derived from *in vitro* studies using primary neural cultures or immortalised or tumour-derived cell lines. Extrapolation of these results to the *in vivo* situation is not always feasible. Stem cell technology does, however, provide a new tool for better understanding the adverse reactions induced by environmental hazards[13]. Stem cell technology is especially useful for developmental neurotoxicology research because stem cells are widely represented in developing systems[14]. Embryonic neural stem cells (eNSCs) are considered to be multipotent because they can give rise to the three major cell types of the brain[15]. These cells can be derived from foetal nervous system tissues. The fate decision of eNSCs is critical for brain development[16]. This includes processes such as proliferation of eNSCs, neuronal and glial cell differentiation, cell death, and the development of neurites. For these reasons, eNSCs represent the developing brain in most situations. Embryonic NSCs have been widely used for the analysis

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Pathophysiology xxx (2009) xxx–xxx

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Electromagnetic pollution from phone masts. Effects on wildlife

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Received 10 August 2008; received in revised form 28 August 2008; accepted 30 January 2009

Abstract

A review on the impact of radiofrequency radiation from wireless telecommunications on wildlife is presented. Electromagnetic radiation is a form of environmental pollution which may hurt wildlife. Phone masts located in their living areas are irradiating continuously some species that could suffer long-term effects, like reduction of their natural defenses, deterioration of their health, problems in reproduction and reduction of their useful territory through habitat deterioration. Electromagnetic radiation can exert an aversive behavioral response in rats, bats and birds such as sparrows. Therefore microwave and radiofrequency pollution constitutes a potential cause for the decline of animal populations and deterioration of health of plants living near phone masts. To measure these effects urgent specific studies are necessary.

Keywords: Effects on wildlife; Effects on birds; Electromagnetic radiation; Mammals; Microwaves; Mobile telecommunications; Non-thermal effects; Phone masts; Radiofrequencies

1. Introduction

Life has evolved under the influence of two omnipresent forces: gravity and electromagnetism. It should be expected that both play important roles in the functional activities of organisms [1]. Before the 1990's radiofrequencies were mainly from a few radio and television transmitters, located in remote areas and/or very high places. Since the introduction of wireless telecommunication in the 1990's the rollout of phone networks has caused a massive increase in electromagnetic pollution in cities and the countryside [2,3].

Multiple sources of mobile communication result in chronic exposure of a significant part of the wildlife (and man) to microwaves at non-thermal levels [4]. In recent years, wildlife has been chronically exposed to microwaves and RFR (Radiofrequency radiation) signals from various sources, including GSM and UMTS/3G wireless phones and base stations, WLAN (Wireless Local Area Networks), WPAN (Wireless Personal Area Networks such as Bluetooth), and DECT (Digital Enhanced (former European) Cordless Telecommunications) that are erected indiscriminately without studies of environmental impact measuring long-term effects. These exposures are characterized by low intensities, varieties of signals, and long-term durations. The greater portion of this exposure is from mobile telecommunications (geometric mean in Vienna: 73% [5]). In Germany the GSM cellular phone tower radiation is the dominating high frequency source in residential areas [6]. Also GSM is the dominating high frequency source in the wilderness of Spain (personal observation).

Numerous experimental data have provided strong evidence of athermal microwave effects and have also indicated several regularities in these effects: dependence of frequency within specific frequency windows of "resonance-type"; dependence on modulation and polarization; dependence on intensity within specific intensity windows, including super-low power density comparable with intensities from base stations/masts [4,7–9]. Some studies have demonstrated different microwave effects depending on wavelength in the range of mm, cm or m [10,11]. Duration of exposure may be as important as power density. Biological effects resulting from electromagnetic field radiation might depend on dose, which indicates long-term accumulative effects [3,9,12]. Modulated and pulsed radiofrequencies seem to be more effective in producing effects [4,9]. Pulsed waves (in blasts), as well as certain low frequency modulations exert greater

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0928-4680/$ – see front matter © 2009 Published by Elsevier Ireland Ltd.
doi:10.1016/j.pathophys.2009.01.007

Please cite this article in press as: A. Balmori, Electromagnetic pollution from phone masts. Effects on wildlife, Pathophysiology (2009), doi:10.1016/j.pathophys.2009.01.007

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Pathophysiology xxx (2009) xxx–xxx

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Public health implications of wireless technologies

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Received 18 January 2008; accepted 30 January 2009

Abstract

Global exposures to emerging wireless technologies from applications including mobile phones, cordless phones, DECT phones, WI-FI, WLAN, WiMAX, wireless internet, baby monitors, and others may present serious public health consequences. Evidence supporting a public health risk is documented in the BioInitiative Report. New, biologically based public exposure standards for chronic exposure to low-intensity exposures are warranted. Existing safety standards are obsolete because they are based solely on thermal effects from acute exposures. The rapidly expanding development of new wireless technologies and the long latency for the development of such serious diseases as brain cancers means that failure to take immediate action to reduce risks may result in an epidemic of potentially fatal diseases in the future. Regardless of whether or not the associations are causal, the strengths of the associations are sufficiently strong that in the opinion of the authors, taking action to reduce exposures is imperative, especially for the fetus and children. Such action is fully compatible with the precautionary principle, as enunciated by the Rio Declaration, the European Constitution Principle on Health (Section 3.1) and the European Union Treaties Article 174.

Keywords: Wireless technology; Brain cancer; Radiofrequency; Cell phones; Wireless antenna facilities; Childrens' health

1. Introduction and background

Exposure to electromagnetic fields (EMF) has been linked to a variety of adverse health outcomes that may have significant public health consequences [1–13]. The most serious health endpoints that have been reported to be associated with extremely low frequency (ELF) and/or RF include childhood and adult leukemia, childhood and adult brain tumors, and increased risk of the neurodegenerative diseases, Alzheimer's and amyotrophic lateral sclerosis (ALS). In addition, there are reports of increased risk of breast cancer in both men and women, genotoxic effects (DNA damage and micronucleation), pathological leakage of the blood–brain barrier, altered immune function including increased allergic and inflammatory responses, miscarriage and some cardiovascular effects [1–13]. Insomnia (sleep disruption) is reported in studies of people living in very low-intensity RF environments with WI-FI and cell tower-level exposures [85–93]. Short-term effects on cognition, memory and learning, behavior, reaction time, attention and concentration, and altered brainwave activity (altered EEG) are also reported in the scientific literature [94–107]. Biophysical mechanisms that may account for such effects can be found in various articles and reviews [136–144].

The public health implications of emerging wireless technologies are enormous because there has been a very rapid global deployment of both old and new forms in the last 15 years. In the United States, the deployment of wireless infrastructure has accelerated greatly in the last few years with 220,500 cell sites in 2008 [14–16]. Eighty-four percent of the population of the US own cell phones [16]. Annualized wireless revenues in 2008 will reach $144 billion and US spending on wireless communications will reach $212 billion by 2008. Based on the current 15% annual growth rate enjoyed by the wireless industry, in the next 5 years wireless will become a larger sector of the US economy than both the agriculture and automobile sectors. The annualized use of cell phones in the US is estimated to be 2.23 trillion minutes in 2008 [16]. There are 2.2 billion users of cell phones worldwide in 2008 [17] and many million more users of cordless phones.

Over 75 billion text messages were sent in the United States, compared with 7.2 billion in June 2005, according to

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0928-4680/$ – see front matter © 2009 Elsevier Ireland Ltd. All rights reserved.
doi:10.1016/j.pathophys.2009.01.011

Please cite this article in press as: C. Sage, D.O. Carpenter, Public health implications of wireless technologies, Pathophysiology (2009), doi:10.1016/j.pathophys.2009.01.011

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Pathophysiology xxx (2009) xxx–xxx

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Reproductive and developmental effects of EMF in vertebrate animal models

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Received 10 August 2008; received in revised form 28 August 2008; accepted 30 January 2009

Abstract

This paper reviews the literature data on the effects of electromagnetic fields (EMF), in the reproductive organs as well as in prenatal and postnatal development of vertebrate animals. Review articles which have been published till 2001, regarding the reproductive and developmental effects of the entire range of frequency of electromagnetic fields, were surveyed. Experimental studies which were published from 2001 onwards were summarized. Special focus on the effects of radiofrequencies related to mobile communication in the above mentioned topics has been made. According to the majority of the investigations, no strong effects resulted regarding the exposure to EMF of mobile telephony in the animal reproduction and development. However further research should be done in order to clarify many unknown aspects of the impact of EMF in the living organisms.

Keywords: Electromagnetic fields (EMF); Mobile phones; Teratology; Endometrium; Testis

1. Introduction

During the 20th century, the exposure to electromagnetic fields (EMF) became an important source of concern about the possible effects in the living organisms. The artificial sources of electromagnetic radiation have risen tremendously because of the ongoing needs on electricity, telecommunications, and electronic devices. In this context, World Health Organisation (WHO) established in 1996 the International EMF project in order to assess health and environmental effects of exposure to EMF in the frequency range from 0 to 300 GHz. For the purpose of this paper this range will be divided into static (0 Hz), extremely low frequency (ELF > 0–300 kHz), intermediate frequencies (IF > 300–10 MHz) and radiofrequency (RF 10 MHz–300 GHz) fields [J. Juutilainen, Developmental effects of electromagnetic fields, Bioelectromagnetics 7 (2005) S107–S115]. The mobile phone technology is based on radiofrequency radiation with transmission of microwaves carrying frequencies between 880 and 1800 MHz [P.A. Valberg, T.E. van Deventer, M.H. Repacholi, Workgroup report: base stations and wireless networks-radiofrequency (RF) exposures and health consequences, Environ. Health Perspect. 115 (2007) 416–424].

The mobile telephony revolution took place in the last decade. There is an increasing number of cell phone users all over the world. Also, new technologies which use the spectrum of high frequency emissions are incorporated in many aspects of telecommunications. As a consequence, there is a lot of interest about the possible effects of the radiation emitted from the machines which are engaged in the telephony such as hand phones, base stations and transmitters.

The biological effects of EMF have been and are being investigated on different levels of organization. On the level of human populations, epidemiological studies are used whereas, on the level of individuals human, animal and plant *in vivo* experiments are carried out. Furthermore, on the level of organs, tissues and cells *in vitro* investigations are employed. Finally, on the sub-cellular level, biochemical and molecular techniques are utilized.

From another point of view, many studies have been carried out or are in progress about the various effects of radiation emissions regarding the behaviour, cancer, central nervous system, sleep, children, cardiovascular system, immune function, reproduction and development [3].

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doi:10.1016/j.pathophys.2009.01.010

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Pathophysiology xxx (2009) xxx–xxx

ISP PATHOPHYSIOLOGY

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Electromagnetic pollution from phone masts. Effects on wildlife

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0928-4680/$ – see front matter © 2009 Published by Elsevier Ireland Ltd.
doi:10.1016/j.pathophys.2009.01.007

Please cite this article in press as: A. Balmori, Electromagnetic pollution from phone masts. Effects on wildlife, Pathophysiology (2009), doi:10.1016/j.pathophys.2009.01.007

Journal of Chemical Neuroanatomy 75 (2016) 123–127

Contents lists available at ScienceDirect

Journal of Chemical Neuroanatomy

journal homepage: www.elsevier.com/locate/jchemneu

Effects of GSM modulated radio-frequency electromagnetic radiation on permeability of blood–brain barrier in male & female rats

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ARTICLE INFO

Article history:
Received 15 July 2015
Received in revised form 8 December 2015
Accepted 10 December 2015
Available online 23 December 2015

Keywords:
Blood–brain barrier (BBB)
Evans blue (EB)
Radio frequency radiation (RFR)
Rats
Mobile phones

ABSTRACT

With the increased use of mobile phones, their biological and health effects have become more important. Usage of mobile phones near the head increases the possibility of effects on brain tissue. This study was designed to investigate the possible effects of pulse modulated 900 MHz and 1800 MHz radio-frequency radiation on the permeability of blood–brain barrier of rats. Study was performed with 6 groups of young adult male and female wistar albino rats. The permeability of blood-brain barrier to intravenously injected evans blue dye was quantitatively examined for both control and radio-frequency radiarion exposed groups. For male groups; Evans blue content in the whole brain was found to be 0.08 ± 0.01 mg% in the control, 0.13 ± 0.03 mg% in 900 MHz exposed and 0.26 ± 0.05 mg% in 1800 MHz exposed animals. In both male radio-frequency radiation exposed groups, the permeability of blood–brain barrier found to be increased with respect to the controls ($p < 0.01$). 1800 MHz pulse modulated radio-frequency radiation exposure was found more effective on the male animals ($p < 0.01$). For female groups; dye contents in the whole brains were 0.14 ± 0.01 mg% in the control, 0.24 ± 0.03 mg% in 900 MHz exposed and 0.14 ± 0.02 mg% in 1800 MHz exposed animals. No statistical variance found between the control and 1800 MHz exposed animals ($p > 0.01$). However 900 MHz pulse modulated radio-frequency exposure was found effective on the permeability of blood-brain barrier of female animals. Results have shown that 20 min pulse modulated radio-frequency radiation exposure of 900 MHz and 1800 MHz induces an effect and increases the permeability of blood-brain barrier of male rats. For females, 900 MHz was found effective and it could be concluded that this result may due to the physiological differences between female and male animals. The results of this study suggest that mobile phone radation could lead to increase the permeability of blood-brain barrier under non-thermal exposure levels. More studies are needed to demonstrate the mechanisms of that breakdown.

1. Introduction

Blood–brain barrier (BBB) behaves like a selective filter which does not allow most of molecules to enter the brain under normal physiological condition (Koziara et al., 2006). It is due to tight junctions linking together endothelial cells of cerebral blood vessels. Except for lipohilic molecules which able to cross the cell inner- and outer membrane, all blood-borne materials are carried across endothelial cells by active and regulated mechanisms. Under some pathological conditions (such as hyperthermia, acute rise in arterial pressure, brain trauma, old age, MS and Alzheimer diseases, diabetes, exposure to non-ionizing/ionizing radiations . . .) BBB permeability increases for substances normally excluded such as large molecules that have no lipid solubility.

Mobile phones and related base stations are becoming a widespread source of radio-frequency radiation - RFR which is the part of non-ionizing radiation. Antenna is very close to the user's head during its normal use and there is concern about the level of microwave radiation to which the brain is being exposed. There are various reports about the link on the use of mobile telephones with headaches (Sandstrom et al., 2001), brain cancer (Muscat et al., 2006; Hardell and Mild, 2006) and the permeability of BBB.

Oscar and Hawkins performed early studies on the effects of RF on BBB (Oscar and Hawkins, 1977) and they observed that, the fields at very low energy levels caused a significant leakage of ^{14}C mannitol, innulin and dextran from the capillaries into the surrounding cerebellar brain tissue. These findings were not confirmed in another study using ^{14}C-sucrose (Gruenau et al., 1982). Shivers et al. (1987) and Prato et al. (1990) investigated the

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http://dx.doi.org/10.1016/j.jchemneu.2015.12.010
0891-0618/

ELSEVIER

Pathophysiology xxx (2013) xxx–xxx

ISP PATHOPHYSIOLOGY

www.elsevier.com/locate/pathophys

Autism and EMF? Plausibility of a pathophysiological link – Part I

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Received 10 February 2013; received in revised form 6 May 2013; accepted 15 July 2013

Abstract

Although autism spectrum conditions (ASCs) are defined behaviorally, they also involve multileveled disturbances of underlying biology that find striking parallels in the physiological impacts of electromagnetic frequency and radiofrequency exposures (EMF/RFR). Part I of this paper will review the critical contributions pathophysiology may make to the etiology, pathogenesis and ongoing generation of core features of ASCs. We will review pathophysiological damage to core cellular processes that are associated both with ASCs and with biological effects of EMF/RFR exposures that contribute to chronically disrupted homeostasis. Many studies of people with ASCs have identified oxidative stress and evidence of free radical damage, cellular stress proteins, and deficiencies of antioxidants such as glutathione. Elevated intracellular calcium in ASCs may be due to genetics or may be downstream of inflammation or environmental exposures. Cell membrane lipids may be peroxidized, mitochondria may be dysfunctional, and various kinds of immune system disturbances are common. Brain oxidative stress and inflammation as well as measures consistent with blood–brain barrier and brain perfusion compromise have been documented. Part II of this paper will review how behaviors in ASCs may emerge from alterations of electrophysiological oscillatory synchronization, how EMF/RFR could contribute to these by de-tuning the organism, and policy implications of these vulnerabilities. Changes in brain and autonomic nervous system electrophysiological function and sensory processing predominate, seizures are common, and sleep disruption is close to universal. All of these phenomena also occur with EMF/RFR exposure that can add to system overload ('allostatic load') in ASCs by increasing risk, and worsening challenging biological problems and symptoms; conversely, reducing exposure might ameliorate symptoms of ASCs by reducing obstruction of physiological repair. Various vital but vulnerable mechanisms such as calcium channels may be disrupted by environmental agents, various genes associated with autism or the interaction of both. With dramatic increases in reported ASCs that are coincident in time with the deployment of wireless technologies, we need aggressive investigation of potential ASC – EMF/RFR links. The evidence is sufficient to warrant new public exposure standards benchmarked to low-intensity (non-thermal) exposure levels now known to be biologically disruptive, and strong, interim precautionary practices are advocated.

Keywords: Autism; EMF/RFR; Cellular stress; Oxidative stress; Mitochondrial dysfunction; Oscillatory synchronization; Environment; Radiofrequency; Wireless; Children; Fetus

1. Introduction

The premise of this review is that although scant attention has been paid to possible links between electromagnetic fields and radiofrequency radiation exposures (EMF/RFR) and Autism Spectrum Conditions (ASCs), such links probably exist. The rationale for this premise is that the physiological impacts of EMF/RFR and a host of increasingly well-documented pathophysiological phenomena in ASCs have remarkable similarities, spanning from cellular and oxidative stress to malfunctioning membranes, channels and barriers to genotoxicity, mitochondrial dysfunction, immune abnormalities, inflammatory issues, neuropathological disruption and electrophysiological dysregulation – in short, multi-scale contributors to de-tuning the organism. Additional support may be found in the parallels between the rise in reported cases of ASCs and the remarkable increases in EMF/RFR exposures over the past few decades

Reviewing these similarities does not prove that these parallels imply causality. Moreover, the physiological processes affected by EMF/RFR are also impacted by other environmental factors, and are known to be present in myriad other chronic illnesses. A set of in-depth reviews on the

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0928-4680/$ – see front matter © 2013 Elsevier Ireland Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.pathophys.2013.08.001

Journal of Chemical Neuroanatomy 75 (2016) 43–51

Contents lists available at ScienceDirect

Journal of Chemical Neuroanatomy

journal homepage: www.elsevier.com/locate/jchemneu

Review

Microwave frequency electromagnetic fields (EMFs) produce widespread neuropsychiatric effects including depression

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ARTICLE INFO

Article history:
Received 13 April 2015
Received in revised form 1 August 2015
Accepted 9 August 2015
Available online 21 August 2015

Keywords:
Excessive calcium effects
Oxidative/nitrosative stress
Low-intensity microwave electromagnetic fields

ABSTRACT

Non-thermal microwave/lower frequency electromagnetic fields (EMFs) act via voltage-gated calcium channel (VGCC) activation. Calcium channel blockers block EMF effects and several types of additional evidence confirm this mechanism. Low intensity microwave EMFs have been proposed to produce neuropsychiatric effects, sometimes called microwave syndrome, and the focus of this review is whether these are indeed well documented and consistent with the known mechanism(s) of action of such EMFs. VGCCs occur in very high densities throughout the nervous system and have near universal roles in release of neurotransmitters and neuroendocrine hormones. Soviet and Western literature shows that much of the impact of non-thermal microwave exposures in experimental animals occurs in the brain and peripheral nervous system, such that nervous system histology and function show diverse and substantial changes. These may be generated through roles of VGCC activation, producing excessive neurotransmitter/neuroendocrine release as well as oxidative/nitrosative stress and other responses. Excessive VGCC activity has been shown from genetic polymorphism studies to have roles in producing neuropsychiatric changes in humans. Two U.S. government reports from the 1970s to 1980s provide evidence for many neuropsychiatric effects of non-thermal microwave EMFs, based on occupational exposure studies. 18 more recent epidemiological studies, provide substantial evidence that microwave EMFs from cell/mobile phone base stations, excessive cell/mobile phone usage and from wireless smart meters can each produce similar patterns of neuropsychiatric effects, with several of these studies showing clear dose–response relationships. Lesser evidence from 6 additional studies suggests that short wave, radio station, occupational and digital TV antenna exposures may produce similar neuropsychiatric effects. Among the more commonly reported changes are sleep disturbance/insomnia, headache, depression/depressive symptoms, fatigue/tiredness, dysesthesia, concentration/attention dysfunction, memory changes, dizziness, irritability, loss of appetite/body weight, restlessness/anxiety, nausea, skin burning/tingling/dermographism and EEG changes. In summary, then, the mechanism of action of microwave EMFs, the role of the VGCCs in the brain, the impact of non-thermal EMFs on the brain, extensive epidemiological studies performed over the past 50 years, and five criteria testing for causality, all collectively show that various non-thermal microwave EMF exposures produce diverse neuropsychiatric effects.

Contents

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http://dx.doi.org/10.1016/j.jchemneu.2015.08.001

ELSEVIER

Pathophysiology xxx (2013) xxx–xxx

ISP PATHOPHYSIOLOGY

www.elsevier.com/locate/pathophys

Autism and EMF? Plausibility of a pathophysiological link part II

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Abstract

Autism spectrum conditions (ASCs) are defined behaviorally, but they also involve multileveled disturbances of underlying biology that find striking parallels in the physiological impacts of electromagnetic frequency and radiofrequency radiation exposures (EMF/RFR). Part I (Vol 776) of this paper reviewed the critical contributions pathophysiology may make to the etiology, pathogenesis and ongoing generation of behaviors currently defined as being core features of ASCs. We reviewed pathophysiological damage to core cellular processes that are associated both with ASCs and with biological effects of EMF/RFR exposures that contribute to chronically disrupted homeostasis. Many studies of people with ASCs have identified oxidative stress and evidence of free radical damage, cellular stress proteins, and deficiencies of antioxidants such as glutathione. Elevated intracellular calcium in ASCs may be due to genetics or may be downstream of inflammation or environmental exposures. Cell membrane lipids may be peroxidized, mitochondria may be dysfunctional, and various kinds of immune system disturbances are common. Brain oxidative stress and inflammation as well as measures consistent with blood–brain barrier and brain perfusion compromise have been documented. Part II of this paper documents how behaviors in ASCs may emerge from alterations of electrophysiological oscillatory synchronization, how EMF/RFR could contribute to these by de-tuning the organism, and policy implications of these vulnerabilities. It details evidence for mitochondrial dysfunction, immune system dysregulation, neuroinflammation and brain blood flow alterations, altered electrophysiology, disruption of electromagnetic signaling, synchrony, and sensory processing, de-tuning of the brain and organism, with autistic behaviors as emergent properties emanating from this pathophysiology. Changes in brain and autonomic nervous system electrophysiological function and sensory processing predominate, seizures are common, and sleep disruption is close to universal. All of these phenomena also occur with EMF/RFR exposure that can add to system overload ('allostatic load') in ASCs by increasing risk, and can worsen challenging biological problems and symptoms; conversely, reducing exposure might ameliorate symptoms of ASCs by reducing obstruction of physiological repair. Various vital but vulnerable mechanisms such as calcium channels may be disrupted by environmental agents, various genes associated with autism or the interaction of both. With dramatic increases in reported ASCs that are coincident in time with the deployment of wireless technologies, we need aggressive investigation of potential ASC—EMF/RFR links. The evidence is sufficient to warrant new public exposure standards benchmarked to low-intensity (non-thermal) exposure levels now known to be biologically disruptive, and strong, interim precautionary practices are advocated.

Keywords: Autism; EMF/RFR; Cellular stress; Oxidative stress; Mitochondrial dysfunction; Oscillatory synchronization; Environment; Radiofrequency; Wireless; Children; Fetus; Microwave

1. Recap of part I and summary of part II

Part I of this two-part article previously documented a series of parallels between the pathophysiological and genotoxic impacts of EMF/RFR and the pathophysiological, genetic and environmental underpinnings of ASCs. DNA damage, immune and blood–brain barrier disruption, cellular and oxidative stress, calcium channel dysfunction, disturbed circadian rhythms, hormone dysregulation, and degraded cognition, sleep, autonomic regulation and brainwave activity—all are associated with both ASCs and EMF/RFR; and the disruption of fertility and reproduction associated with EMF/RFR may also be related to the increasing incidence of ASCs. All of this argues for reduction of exposures now, and better coordinated research in these areas. These

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0928-4680/$ – see front matter © 2013 Elsevier Ireland Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.pathophys.2013.08.002

Research Signpost
37/661 (2), Fort P.O.
Trivandrum-695 023
Kerala, India

Review Article

Recent Res. Devel. Mol. Cell. Biol., 7(2014): 0-00 ISBN: 978-81-308-0000-0

1. Microwave electromagnetic fields act by activating voltage-gated calcium channels: why the current international safety standards do not predict biological hazard

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Abstract. Microwave and other low frequency electromagnetic fields (EMFs) have been shown to act by activating voltage-gated calcium channels (VGCCs) with most biological effects being due to elevated intracellular calcium, consequent nitric oxide (NO) elevation and either peroxynitrite or NO signaling. This, the role of excessive intracellular calcium in microwave effects and some 20,000 papers on microwave biological effects show that the current international safety standards do not predict biological hazard. Such standards are based on the false assumption that the predominant effects of microwave and other low frequency EMF exposures are due to heating. A whole series of biological changes reportedly produced by microwave exposures can now be explained in terms of this new paradigm of EMF action via VGCC activation, including: oxidative stress; single and double stranded breaks in cellular DNA; therapeutic effects; blood-brain barrier breakdown; greatly depressed melatonin levels and sleep disruption; cancer; male and

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Journal of Microscopy and Ultrastructure xxx (2014) xxx–xxx

Contents lists available at ScienceDirect

Journal of Microscopy and Ultrastructure

journal homepage: www.elsevier.com/locate/jmau

Review

Why children absorb more microwave radiation than adults: The consequences

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ARTICLE INFO

Article history:
Received 4 April 2014
Received in revised form 3 June 2014
Accepted 24 June 2014
Available online xxx

Keywords:
Tumors
Myelin
Carcinogen
Fetus
Children
Latency

ABSTRACT

Computer simulation using MRI scans of children is the only possible way to determine the microwave radiation (MWR) absorbed in specific tissues in children. Children absorb more MWR than adults because their brain tissues are more absorbent, their skulls are thinner and their relative size is smaller. MWR from wireless devices has been declared a possible human carcinogen. Children are at greater risk than adults when exposed to any carcinogen. Because the average latency time between first exposure and diagnosis of a tumor can be decades, tumors induced in children may not be diagnosed until well into adulthood. The fetus is particularly vulnerable to MWR. MWR exposure can result in degeneration of the protective myelin sheath that surrounds brain neurons. MWR-emitting toys are being sold for use by young infants and toddlers. Digital dementia has been reported in school age children. A case study has shown when cellphones are placed in teenage girls' bras multiple primary breast cancer develop beneath where the phones are placed. MWR exposure limits have remained unchanged for 19 years. All manufacturers of smartphones have warnings which describe the minimum distance at which phone must be kept away from users in order to not exceed the present legal limits for exposure to MWR. The exposure limit for laptop computers and tablets is set when devices are tested 20 cm away from the body. Belgium, France, India and other technologically sophisticated governments are passing laws and/or issuing warnings about children's use of wireless devices.

Contents

Abbreviations: MRI, magnetic resonance imaging; MWR, microwave radiation; CNS, central nervous system; FDTD, finite-difference, time-domain; GBM, glioblastoma multiforme (also called glioblastoma); cm, centimeter.

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http://dx.doi.org/10.1016/j.jmau.2014.06.005
2213-879X/

Electromagnetic Biology and Medicine, 31(1): 34–51, 2012

ISSN: 1536-8378 print / 1536-8386 online
DOI: 10.3109/15368378.2011.622827

informa
healthcare

Exposure Limits: The underestimation of absorbed cell phone radiation, especially in children

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The existing cell phone certification process uses a plastic model of the head called the Specific Anthropomorphic Mannequin (SAM), representing the top 10% of U.S. military recruits in 1989 and greatly underestimating the Specific Absorption Rate (SAR) for typical mobile phone users, especially children. A superior computer simulation certification process has been approved by the Federal Communications Commission (FCC) but is not employed to certify cell phones. In the United States, the FCC determines maximum allowed exposures. Many countries, especially European Union members, use the "guidelines" of International Commission on Non-Ionizing Radiation Protection (ICNIRP), a non governmental agency. Radiofrequency (RF) exposure to a head smaller than SAM will absorb a relatively higher SAR. Also, SAM uses a fluid having the average electrical properties of the head that cannot indicate differential absorption of specific brain tissue, nor absorption in children or smaller adults. The SAR for a 10-year old is up to 153% higher than the SAR for the SAM model. When electrical properties are considered, a child's head's absorption can be over two times greater, and absorption of the skull's bone marrow can be ten times greater than adults. Therefore, a new certification process is needed that incorporates different modes of use, head sizes, and tissue properties. Anatomically based models should be employed in revising safety standards for these ubiquitous modern devices and standards should be set by accountable, independent groups.

INTRODUCTION

History of Exposure Testing, Guidelines, and Standard-Setting

August 1974

In 1974, a study determined that at certain frequency ranges resonance increased the absorbed radiation by up to nine times higher than that previously assumed for humans (Gandhi, 1974).

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ELECTROMAGNETIC BIOLOGY AND MEDICINE

http://informahealthcare.com/ebm
ISSN: 1536-8378 (print), 1536-8386 (electronic)

Electromagn Biol Med, Early Online: 1–16
 DOI: 10.3109/15368378.2015.1043557

informa healthcare

REVIEW ARTICLE

Oxidative mechanisms of biological activity of low-intensity radiofrequency radiation

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Abstract

This review aims to cover experimental data on oxidative effects of low-intensity radiofrequency radiation (RFR) in living cells. Analysis of the currently available peer-reviewed scientific literature reveals molecular effects induced by low-intensity RFR in living cells; this includes significant activation of key pathways generating reactive oxygen species (ROS), activation of peroxidation, oxidative damage of DNA and changes in the activity of antioxidant enzymes. It indicates that among 100 currently available peer-reviewed studies dealing with oxidative effects of low-intensity RFR, in general, 93 confirmed that RFR induces oxidative effects in biological systems. A wide pathogenic potential of the induced ROS and their involvement in cell signaling pathways explains a range of biological/health effects of low-intensity RFR, which include both cancer and non-cancer pathologies. In conclusion, our analysis demonstrates that low-intensity RFR is an expressive oxidative agent for living cells with a high pathogenic potential and that the oxidative stress induced by RFR exposure should be recognized as one of the primary mechanisms of the biological activity of this kind of radiation.

Keywords

Cellular signaling, cancer, free radicals, oxidative stress, radiofrequency radiation, reactive oxygen species

History

Received 10 January 2015
Accepted 12 April 2015
Published online 7 July 2015

Introduction

Intensive development of wireless technologies during the last decades led to a dramatic increase of background radiofrequency radiation (RFR) in the human environment. Thus, the level of indoor background RFR in industrialized countries increased 5,000-fold from 1985 to 2005 (Maes, 2005). Such significant environmental changes may have a serious impact on human biology and health. As a proof of such impact, a series of epidemiological studies on the increased risk of tumorigenesis in ''heavy'' users of wireless telephony exists (Hardell et al., 2007, 2011; Sadetzki et al., 2008; Sato et al., 2011). Some studies indicate that long-term RFR exposure in humans can cause various non-cancer disorders, e.g., headache, fatigue, depression, tinnitus, skin irritation, hormonal disorders and other conditions (Abdel-Rassoul et al., 2007; Buchner & Eger, 2011; Chu et al., 2011; Johansson, 2006; Santini et al., 2002; Yakymenko et al., 2011). In addition, convincing studies on hazardous effects of RFR in human germ cells have been published (Agarwal et al., 2009; De Iuliis et al., 2009).

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All abovementioned studies dealt with the effects of low-intensity RFR. This means that the intensity of radiation was far below observable thermal effects in biological tissues, and far below safety limits of the International Commissions on Non-Ionizing Radiation Protection (ICNIRP) (ICNIRP, 1998). To date, molecular mechanisms of non-thermal effects of RFR are still a bottleneck in the research on the biological/health effects of low-intensity RFR, although recently many studies have been carried out on metabolic changes in living cells under low-intensity RFR, and comprehensive reviews were published (Belyaev, 2010; Consales et al., 2012; Desai et al., 2009; Yakymenko et al., 2011). In the present work, we analyze the results of molecular effects of low-intensity RFR in living cells and model systems, with a special emphasis on oxidative effects and free radical mechanisms. It might seem paradoxical that, despite being non-ionizing, RFR can induce significant activation of free radical processes and overproduction of reactive oxygen species (ROS) in living cells. We believe that the analysis of recent findings will allow recognition of a general picture of the potential health effects of already ubiquitous and ever-increasing RFR.

Radiofrequency radiation

RFR is a part of electromagnetic spectrum with frequencies from 30 kHz to 300 GHz. RFR is classified as non-ionizing,

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BRAIN RESEARCH

Research Report

Effects of prenatal exposure to a 900 MHz electromagnetic field on the dentate gyrus of rats: a stereological and histopathological study☆

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ARTICLE INFO

Article history:
Accepted 5 August 2008
Available online 16 August 2008

Keywords:
Electromagnetic field
Dentate gyrus
Granule cell
Stereology
Optical fractionator
Rat

ABSTRACT

Electromagnetic fields (EMFs) inhibit the formation and differentiation of neural stem cells during embryonic development. In this study, the effects of prenatal exposure to EMF on the number of granule cells in the dentate gyrus of 4-week-old rats were investigated. This experiment used a control (Cont) group and an EMF exposed (EMF) group (three pregnant rats each group). The EMF group consisted of six offspring ($n=6$) of pregnant rats that were exposed to an EMF of up to 900 megahertz (MHz) for 60 min/day between the first and last days of gestation. The control group consisted of five offspring ($n=5$) of pregnant rats that were not treated at all. The offspring were sacrificed when they were 4 weeks old. The numbers of granule cells in the dentate gyrus were analyzed using the optical fractionator technique. The results showed that prenatal EMF exposure caused a decrease in the number of granule cells in the dentate gyrus of the rats ($P<0.01$). This suggests that prenatal exposure to a 900 MHz EMF affects the development of the dentate gyrus granule cells in the rat hippocampus. Cell loss might be caused by an inhibition of granule cell neurogenesis in the dentate gyrus.

1. Introduction

Neurons in most regions of the brain are formed during gestation and the process of neurogenesis is completed before birth (Guidi et al., 2005). Because of this developmental pattern, the adult brain is unable to replace nerve cells lost as a result of aging or pathological conditions, except for the dentate gyrus (DG) in the hippocampus and the subventricular zone of the lateral ventricle in several mammals' brains (Contestabile, 2002; Guidi et al., 2005). In these regions, neurogenesis begins during gestation, continues during the early postnatal period and, at a slower rate, through into adulthood. This is true for all species, including humans (Eriksson et al., 1998; Snyder et al., 2001; Magavi and Macklis, 2002; Guidi et al., 2005).The principle neuron type of the DG is granule cells, the production of which begins in the prenatal period and continues throughout postnatal life. However, many of these cells are formed by the third-week after birth (Rodier, 1980). Therefore, deleterious events during gestation may induce neurobiological or behavioral defects in offspring, including hippocampal formation, because this region is vulnerable to disruptive events (Lemaire et al., 2000).

☆ This study was presented at the 9th National Congress of Histology and Embryology, Turkey, Adana, May 20-23, 2008.

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0006-8993/$ – see front matter © 2008 Elsevier B.V. All rights reserved.
doi:10.1016/j.brainres.2008.08.013

Electromagnetic fields (EMFs) can influence neuronal functions, including regulation of synaptic plasticity, neurotransmitter release, neuronal survival, learning and memory (Sakatani et al., 2002; Manikonda et al., 2007). It also induces cell death and inhibits the differentiation of neural stem cells into neurons during embryonic development (Salford et al., 2003). Therefore, it is claimed that prenatal exposure to EMFs could disturb granule cell neurogenesis in the DG, resulting in disturbed postnatal behavioral and cognitive functions related to the hippocampus (Hocking, 1998; Mausset et al., 2001). In the presented study, the effect of prenatal exposure to a 900 megahertz (MHz) EMF on the amount of granule cells in the DG of 4-week-old (4W-old) rats was investigated using the optical fractionator technique. Additionally, sections of the DGs obtained from both the control and experimental groups were histopathologically examined.

Table 1 – Mean values of total granule cell numbers, CV and CE of stereological analysis, mean dissector number, section thickness and number of steps for estimation of total neuron number in the DG of Cont and EMF groups of 4W-old rats

	Cont Group ($n=5$)	EMF Group ($n=6$)
Total granule cell number[a]	1,235,702±21,731	994,188±21,772[b]
CE	0.05	0.04
CV	0.04	0.05
Dissector particle number	428	351
Section thickness (μm)	28.72	28.11
Number of steps for counting	178	175
Number of sampled sections	14.6	15

[a] Values are as mean±SEM. DG, dentate gyrus; Cont, control group; EMF, electromagnetic field exposed group; MHz, megahertz; CE, coefficient of error; CV, coefficient of variation.
[b] $P<0.01$.

2. Results

2.1. *Histopathological observations*

At the end of the 4th week, the histological appearance of the Cont and EMF groups' DGs were examined. The results are shown in Fig. 1. At the light microscopic level, the morphology of the granule cells was normal in the control rats. However, in the depths of the EMF group's DGs, darkly stained neurons were easily seen among the normal granule cells (Fig. 1).

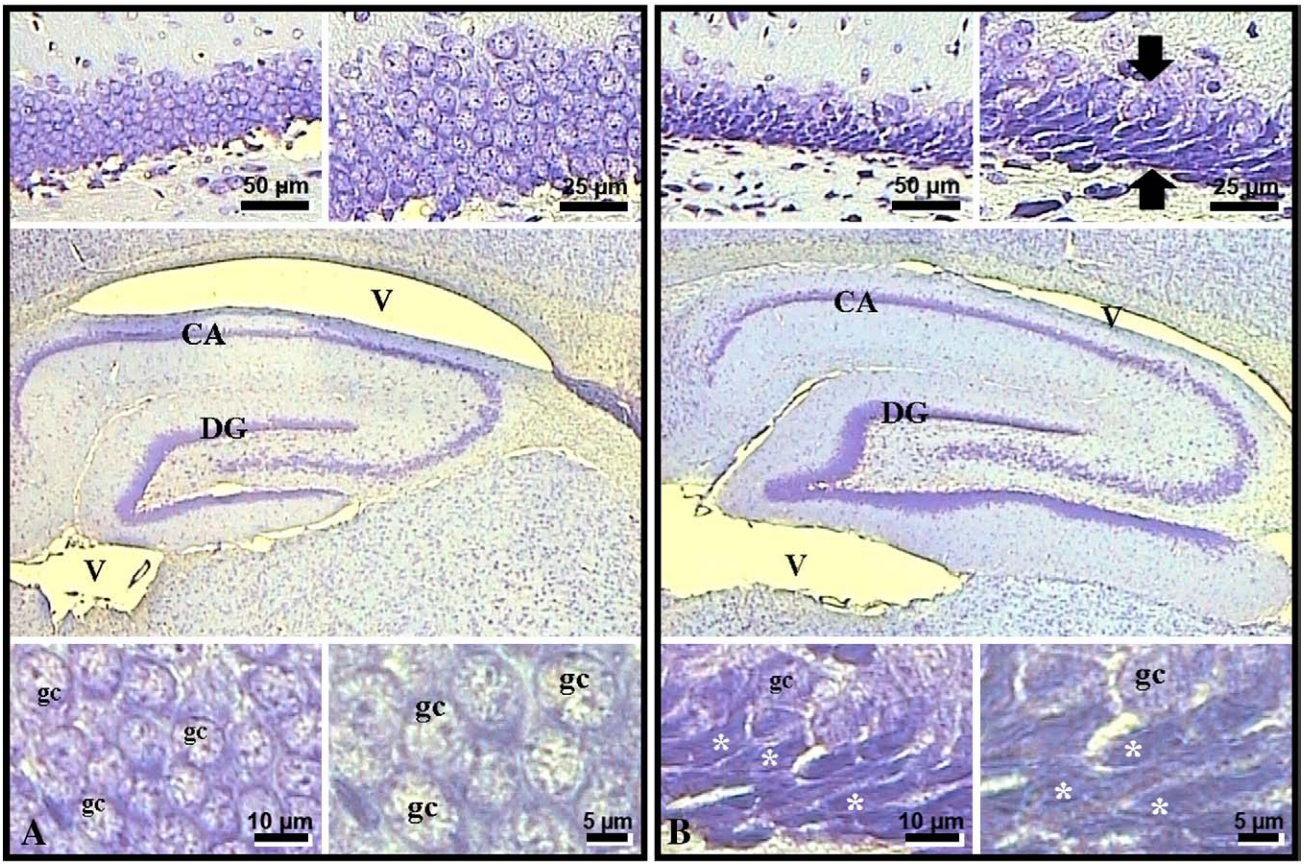

Fig. 1 – Representative photomicrographs of DGs belong to the Cont (A) and EMF (B) groups. Although granular cells of DG in the Cont group were normal in structures, but most of granular cells in the medial region of DG in the EMF group were condensed seen as dark-blue cells are interspersed among the normal nerve cells (*). Upper and bottom rows of each plate (A and B) show magnified the same area of DG. Arrows point to condensed cells. DG, dentate gyrus; Cont, control group; EMF, electromagnetic field group; V, ventricle; CA, cornu ammonis; DG, dentate gyrus; gc, granular cell; Cresyl fast violet staining.

Appl Biochem Biotechnol (2013) 169:1727–1751
DOI 10.1007/s12010-012-0079-9

2.45 GHz Microwave Irradiation-Induced Oxidative Stress Affects Implantation or Pregnancy in Mice, *Mus musculus*

Saba Shahin · Vineet Prakash Singh · Ritesh K. Shukla · Alok Dhawan · Ravi Kumar Gangwar · Surya Pal Singh · Chandra Mohini Chaturvedi

Received: 17 August 2012 / Accepted: 27 December 2012 /
Published online: 22 January 2013

Abstract The present experiment was designed to study the 2.45 GHz low-level microwave (MW) irradiation-induced stress response and its effect on implantation or pregnancy in female mice. Twelve-week-old mice were exposed to MW radiation (continuous wave for 2 h/day for 45 days, frequency 2.45 GHz, power density=0.033549 mW/cm^2, and specific absorption rate=0.023023 W/kg). At the end of a total of 45 days of exposure, mice were sacrificed, implantation sites were monitored, blood was processed to study stress parameters (hemoglobin, RBC and WBC count, and neutrophil/lymphocyte (N/L) ratio), the brain was processed for comet assay, and plasma was used for nitric oxide (NO), progesterone and estradiol estimation. Reactive oxygen species (ROS) and the activities of ROS-scavenging

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Journal of Chemical Neuroanatomy 75 (2016) 134–139

Contents lists available at ScienceDirect

Journal of Chemical Neuroanatomy

journal homepage: www.elsevier.com/locate/jchemneu

Oxidative stress of brain and liver is increased by Wi-Fi (2.45 GHz) exposure of rats during pregnancy and the development of newborns

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ARTICLE INFO

Article history:
Received 22 September 2015
Received in revised form 15 October 2015
Accepted 16 October 2015
Available online 28 October 2015

Keywords:
Brain
Electromagnetic radiation
Glutathione
Liver
Oxidative stress
Antioxidant vitamins

ABSTRACT

An excessive production of reactive oxygen substances (ROS) and reduced antioxidant defence systems resulting from electromagnetic radiation (EMR) exposure may lead to oxidative brain and liver damage and degradation of membranes during pregnancy and development of rat pups. We aimed to investigate the effects of Wi-Fi-induced EMR on the brain and liver antioxidant redox systems in the rat during pregnancy and development.

Sixteen pregnant rats and their 48 newborns were equally divided into control and EMR groups. The EMR groups were exposed to 2.45 GHz EMR (1 h/day for 5 days/week) from pregnancy to 3 weeks of age. Brain cortex and liver samples were taken from the newborns between the first and third weeks. In the EMR groups, lipid peroxidation levels in the brain and liver were increased following EMR exposure; however, the glutathione peroxidase (GSH-Px) activity, and vitamin A, vitamin E and β-carotene concentrations were decreased in the brain and liver. Glutathione (GSH) and vitamin C concentrations in the brain were also lower in the EMR groups than in the controls; however, their concentrations did not change in the liver.

In conclusion, Wi-Fi-induced oxidative stress in the brain and liver of developing rats was the result of reduced GSH-Px, GSH and antioxidant vitamin concentrations. Moreover, the brain seemed to be more sensitive to oxidative injury compared to the liver in the development of newborns.

1. Introduction

There is currently a widespread use of wireless local area network (WLAN) systems (2.45 GHz) being used as an alternative to wired internet access in many areas including universities, schools, homes and public areas (Nazıroğlu et al., 2013; Dasdag et al., 2015a,b). Several studies have suggested that biological systems might be sensitive to such forms of radiation (Otto and von Mühlendahl, 2007; Takahashi et al., 2010; Çetin et al., 2014; Dasdag et al., 2015a,b). Results of epidemiological (McBride et al., 1999; Burch et al., 2002) and experimental (Tomruk et al., 2010; Özorak et al., 2013; Çetin et al., 2014) studies have reported health risks for public exposure to electromagnetic radiation (EMR). These risks need to be investigated to ensure the safety of women and offspring since these vulnerable individuals are exposed at the same level of environmental EMR as the general population (Otto and von Mühlendahl, 2007; Takahashi et al., 2010; Çetin et al., 2014). During a human pregnancy, EMR exposure may interact with the foetus and result in developmental abnormalities that may potentially cause foetal death or mutations (Mendonca et al., 2011; Nguyen and Goodman, 2012). The biological effects of EMR and their consequences are receiving great interest; however, data on these effects are still scarce and conflicting.

Reactive oxygen substances (ROS) are produced in many physiological functions such as phagocytic activity and mitochondrial functions. ROS induce oxidative injuries in cellular biomolecules

Abbreviations: EMR, electromagnetic radiation; GSH, glutathione; GSH-Px, glutathione peroxidase; LP, lipid peroxidation; PUFAs, polyunsaturated fatty acids; ROS, reactive oxygen species; SAR, specific absorption rate.

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http://dx.doi.org/10.1016/j.jchemneu.2015.10.005
0891-0618/

Environment International 85 (2015) 343–351

Contents lists available at ScienceDirect

Environment International

journal homepage: www.elsevier.com/locate/envint

Memory performance, wireless communication and exposure to radiofrequency electromagnetic fields: A prospective cohort study in adolescents

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ARTICLE INFO

Article history:
Received 10 August 2015
Received in revised form 28 September 2015
Accepted 30 September 2015
Available online xxxx

Keywords:
Mobile phone use
RF-EMF dose
Adolescents
Memory performance

ABSTRACT

Background: The aim of this study is to investigate whether memory performance in adolescents is affected by radiofrequency electromagnetic fields (RF-EMF) from wireless device use or by the wireless device use itself due to non-radiation related factors in that context.
Methods: We conducted a prospective cohort study with 439 adolescents. Verbal and figural memory tasks at baseline and after one year were completed using a standardized, computerized cognitive test battery. Use of wireless devices was inquired by questionnaire and operator recorded mobile phone use data was obtained for a subgroup of 234 adolescents.
RF-EMF dose measures considering various factors affecting RF-EMF exposure were computed for the brain and the whole body.
Data were analysed using a longitudinal approach, to investigate whether cumulative exposure over one year was related to changes in memory performance. All analyses were adjusted for relevant confounders.
Results: The kappa coefficients between cumulative mobile phone call duration and RF-EMF brain and whole body dose were 0.62 and 0.67, respectively for the whole sample and 0.48 and 0.28, respectively for the sample with operator data. In linear exposure–response models an interquartile increase in cumulative operator recorded mobile phone call duration was associated with a decrease in figural memory performance score by −0.15 (95% CI: −0.33, 0.03) units. For cumulative RF-EMF brain and whole body dose corresponding decreases in figural memory scores were −0.26 (95% CI: −0.42, −0.10) and −0.40 (95% CI: −0.79, −0.01), respectively. No exposure-response associations were observed for sending text messages and duration of gaming, which produces tiny RF-EMF emissions.
Conclusions: A change in memory performance over one year was negatively associated with cumulative duration of wireless phone use and more strongly with RF-EMF dose. This may indicate that RF-EMF exposure affects memory performance.

1. Introduction

The use of mobile phones has increased remarkably during the last few years especially in children and adolescents. In 2012, 95% of 12 to 19 years old Swiss adolescents owned a mobile phone (Willemse et al., 2012) and two years later, the proportion had increased to 98% (Willemse et al., 2014). This increase has been accompanied by a growing public concern that radiofrequency electromagnetic fields (RF-EMF) emitted by mobile phones and other sources involved in wireless technology have negative impacts on cognitive functions such as memory. In particular, young people have become the focus of increased attention since memory is important in the context of learning. Memory is involved in storing and retrieving information, and is basically considered as the record left by a learning process (Mc Gill University, 2015).

Studies that investigated a possible effect of RF-EMF exposure on memory tasks in children or adolescents are limited to four experimental studies on acute effects and one epidemiological study. All of these studies focused on reaction time and accuracy of memory. In a double blind randomized crossover trial of thirty-two 10–14 years old adolescents Haarala et al. (2005) revealed no significant effects in the accuracy of any working memory task during a 50 minute exposure to a GSM 900 mobile phone. Using the same exposure conditions Preece et al. (2005) found trends toward higher accuracy in memory tasks in 18 adolescents (10–12 years) participating in a three way crossover experiment. However, none of the results reached statistical significance. Movvahedi et al. (2014) showed that after a mobile phone talk period of 10 min,

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http://dx.doi.org/10.1016/j.envint.2015.09.025
0160-4120/

PLOS ONE

RESEARCH ARTICLE

1800MHz Microwave Induces p53 and p53-Mediated Caspase-3 Activation Leading to Cell Apoptosis *In Vitro*

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Citation: Xing F, Zhan Q, He Y, Cui J, He S, Wang G (2016) 1800MHz Microwave Induces p53 and p53-Mediated Caspase-3 Activation Leading to Cell Apoptosis *In Vitro*. PLoS ONE 11(9): e0163935. doi:10.1371/journal.pone.0163935

Editor: Hiroyasu Nakano, Toho Daigaku, JAPAN

Received: August 15, 2015

Accepted: April 17, 2016

Published: September 30, 2016

Data Availability Statement: All relevant data are within the paper and its Supporting Information files.

Funding: This work was supported by Natural Science Foundation of China (61405062, 91233208 and 61471186), Guangdong Innovative Research Team Program (201001D104799318), Natural Science Foundation of Guangdong Province (S2013040014211, 2014A030313445), Fundamental Research Grant of SUSTC (FRG-SUSTC1501A-38), the Postdoctoral Science Foundation of China (2013M530368, 2014T70818), the Discipline and Specialty Construction Foundation of Colleges and

Abstract

Recent studies have reported that exposure of mammalian cells to microwave radiation may have adverse effects such as induction of cell apoptosis. However, the molecular mechanisms underlying microwave induced mammalian cell apoptosis are not fully understood. Here, we report a novel mechanism: exposure to 1800MHz microwave radiation induces p53-dependent cell apoptosis through cytochrome *c*-mediated caspase-3 activation pathway. We first measured intensity of microwave radiation from several electronic devices with an irradiation detector. Mouse NIH/3T3 and human U-87 MG cells were then used as receivers of 1800MHz electromagnetic radiation (EMR) at a power density of 1209 mW/m^2. Following EMR exposure, cells were analyzed for viability, intracellular reactive oxygen species (ROS) generation, DNA damage, p53 expression, and caspase-3 activity. Our analysis revealed that EMR exposure significantly decreased viability of NIH/3T3 and U-87 MG cells, and increased caspase-3 activity. ROS burst was observed at 6 h and 48 h in NIH/3T3 cells, while at 3 h in U-87 MG cells. Hoechst 33258 staining and in situ TUNEL assay detected that EMR exposure increased DNA damage, which was significantly restrained in the presence of N-acetyl-L-cysteine (NAC, an antioxidant). Moreover, EMR exposure increased the levels of p53 protein and p53 target gene expression, promoted cytochrome *c* release from mitochondrion, and increased caspase-3 activity. These events were inhibited by pretreatment with NAC, pifithrin-α (a p53 inhibitor) and caspase inhibitor. Collectively, our findings demonstrate, for the first time, that 1800MHz EMR induces apoptosis-related events such as ROS burst and more oxidative DNA damage, which in turn promote p53-dependent caspase-3 activation through release of cytochrome *c* from mitochondrion. These findings thus provide new insights into physiological mechanisms underlying microwave-induced cell apoptosis.

2.45 GHz radiofrequency fields alter gene expression in cultured human cells

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Received 20 July 2005; revised 27 July 2005; accepted 27 July 2005

Available online 9 August 2005

Edited by Gianni Cesareni

Abstract The biological effect of radiofrequency (RF) fields remains controversial. We address this issue by examining whether RF fields can cause changes in gene expression. We used the pulsed RF fields at a frequency of 2.45 GHz that is commonly used in telecommunication to expose cultured human HL-60 cells. We used the serial analysis of gene expression (SAGE) method to measure the RF effect on gene expression at the genome level. We observed that 221 genes altered their expression after a 2-h exposure. The number of affected genes increased to 759 after a 6-h exposure. Functional classification of the affected genes reveals that apoptosis-related genes were among the upregulated ones and the cell cycle genes among the downregulated ones. We observed no significant increase in the expression of heat shock genes. These results indicate that the RF fields at 2.45 GHz can alter gene expression in cultured human cells through non-thermal mechanism.

Keywords: Radiofrequency; Biological effect; SAGE; Gene expression

1. Introduction

Radiofrequency (RF) refers to the electromagnetic waves ranging between 10 MHz and 300 GHz. RF have been widely used as a signal carrier in telecommunications. Recent advances in mobile phone technology have resulted in the exponential use of mobile phone communication around the world. The increasing exposure of humans to RF fields has raised wide concerns for potential adverse effects of RF fields on human health (http://www.fcc.gov/oet/rfsafety, http://www.fda.gov/cdrh/phones/index.html, http://www.who.int/emf, http://www.iegmp.org.uk/, http://www.verum-foundation.de/).

While it is clear that high energy-electromagnetic waves, such as X-rays have strong biological effects through ionizing damage, it is uncertain whether the low energy, non-ionizing RF fields could have effects on biological systems. Several epidemiological studies suggest a link between long-term RF exposures and pathological consequences such as cancer [1–7]. Molecular studies also suggest the possible influence of RF fields on various aspects of biological activities [8–13]. Although these studies have provided many clues to the issue of RF biological effects, the results are inconclusive and even controversial.

In this study, we used genome-wide gene expression as the indicator to address the issue of biological effects of RF. We used a 2.45 GHz waveguide system to expose human HL-60 cells. We used the serial analysis of gene expression (SAGE) technique to analyze the RF effect on gene expression at the genome level [14]. Although gene expression has been used as an indicator in previous RF studies, those studies focused only on a handful number of genes pre-selected with defined functions. We aim to provide genome-wide coverage of the expressed genes regardless their functional categories in the RF treated cells to address if RF has biological effects [15,16]. We consider it particularly important to use this approach for the subject that there is limited biological information available. Our study shows that under the conditions used in our experimental system, the 2.45 GHz RF fields caused the expression changes of a number of genes.

2. Materials and methods

2.1. Cell culture

Human HL-60 cell line was purchased from ATCC. Cells were cultured in the RPMI 1640 medium + 10% fetal bovine serum (FBS) in an incubator at 37 °C with 5% CO_2. Cells used for experiments were at the exponential growth phase. Prior to RF exposure, cells were spanned down and re-suspended in 10 ml of fresh medium at the density of 10^6/ml. The cells were then transferred to a 25 ml culture flask for RF exposure.

2.2. RF exposure system

The RF exposure system used for experiments was described in detail (Gerber et al. manuscript in preparation). Briefly, the RF source was a pulsed magnetron (Cober Muegge). It was pulsed at duration

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Abbreviations: RF, radiofrequency; SAGE, serial analysis of gene expression

0014-5793/$30.00 © 2005 Published by Elsevier B.V. on behalf of the Federation of European Biochemical Societies.
doi:10.1016/j.febslet.2005.07.063

Journal of Chemical Neuroanatomy 75 (2016) 116–122

Contents lists available at ScienceDirect

Journal of Chemical Neuroanatomy

journal homepage: www.elsevier.com/locate/jchemneu

Does prolonged radiofrequency radiation emitted from Wi-Fi devices induce DNA damage in various tissues of rats?

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ARTICLE INFO

Article history:
Received 1 July 2015
Received in revised form 5 January 2016
Accepted 5 January 2016
Available online 8 January 2016

Keywords:
2.4 GHz Radiofrequency radiation
DNA damage
Wi-Fi
Comet assay

ABSTRACT

Wireless internet (Wi-Fi) providers have become essential in our daily lives, as wireless technology is evolving at a dizzying pace. Although there are different frequency generators, one of the most commonly used Wi-Fi devices are 2.4 GHz frequency generators. These devices are heavily used in all areas of life but the effect of radiofrequency (RF) radiation emission on users is generally ignored. Yet, an increasing share of the public expresses concern on this issue. Therefore, this study intends to respond to the growing public concern. The purpose of this study is to reveal whether long term exposure of 2.4 GHz frequency RF radiation will cause DNA damage of different tissues such as brain, kidney, liver, and skin tissue and testicular tissues of rats. The study was conducted on 16 adult male Wistar–Albino rats. The rats in the experimental group ($n=8$) were exposed to 2.4 GHz frequency radiation for over a year. The rats in the sham control group ($n=8$) were subjected to the same experimental conditions except the Wi-Fi generator was turned off. After the exposure period was complete the possible DNA damage on the rat's brain, liver, kidney, skin, and testicular tissues was detected through the single cell gel electrophoresis assay (comet) method. The amount of DNA damage was measured as percentage tail DNA value. Based on the DNA damage results determined by the single cell gel electrophoresis (Comet) method, it was found that the% tail DNA values of the brain, kidney, liver, and skin tissues of the rats in the experimental group increased more than those in the control group. The increase of the DNA damage in all tissues was not significant ($p>0.05$). However the increase of the DNA damage in rat testes tissue was significant ($p<0.01$).

In conclusion, long-term exposure to 2.4 GHz RF radiation (Wi-Fi) does not cause DNA damage of the organs investigated in this study except testes. The results of this study indicated that testes are more sensitive organ to RF radiation.

1. Introduction

As the internet plays an important role in modern life, the global usage of Wi-Fi systems has increased dramatically over the last two decades (Foster and Moulder, 2013). Therefore, people everywhere, such as those at home, the workplace, collectively inhabited areas, and schools are exposed to radiofrequency radiation (RF) emitted from mobile phones and Wi-Fi devices (Dasdag et al., 2015a). The increase in the amount of people exposed to RF radiation causes much concern over the application of electromagnetic fields (EMF) and related health risks. In recent years, the adverse health effects of EMF emitted from mobile phones and wireless devices such as Wi-Fi have increased both social and scientific concerns. As the health effects of RF radiation are still not fully known, the Council of Europe has proposed restrictions on Internet access and cell phone usage in all schools to protect the youth from potentially harmful radiation (Watson, 2011). Therefore the detection of molecular mechanisms that explain the harmful effects of the RF radiation transmitted from Wi-Fi devices is very important.

DNA single or double- strand breaks (SSB/DSB) that are unrepairable or improperly repaired primary lesions can cause

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http://dx.doi.org/10.1016/j.jchemneu.2016.01.003
0891-0618/

Appl Biochem Biotechnol (2013) 169:1727–1751
DOI 10.1007/s12010-012-0079-9

2.45 GHz Microwave Irradiation-Induced Oxidative Stress Affects Implantation or Pregnancy in Mice, *Mus musculus*

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Received: 17 August 2012 / Accepted: 27 December 2012 /
Published online: 22 January 2013

Abstract The present experiment was designed to study the 2.45 GHz low-level microwave (MW) irradiation-induced stress response and its effect on implantation or pregnancy in female mice. Twelve-week-old mice were exposed to MW radiation (continuous wave for 2 h/day for 45 days, frequency 2.45 GHz, power density=0.033549 mW/cm^2, and specific absorption rate=0.023023 W/kg). At the end of a total of 45 days of exposure, mice were sacrificed, implantation sites were monitored, blood was processed to study stress parameters (hemoglobin, RBC and WBC count, and neutrophil/lymphocyte (N/L) ratio), the brain was processed for comet assay, and plasma was used for nitric oxide (NO), progesterone and estradiol estimation. Reactive oxygen species (ROS) and the activities of ROS-scavenging

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enzymes— superoxide dismutase, catalase, and glutathione peroxidase—were determined in the liver, kidney and ovary. We observed that implantation sites were affected significantly in MW-irradiated mice as compared to control. Further, in addition to a significant increase in ROS, hemoglobin ($p<0.001$), RBC and WBC counts ($p<0.001$), N/L ratio ($p<0.01$), DNA damage ($p<0.001$) in brain cells, and plasma estradiol concentration ($p<0.05$), a significant decrease was observed in NO level ($p<0.05$) and antioxidant enzyme activities of MW-exposed mice. Our findings led us to conclude that a low level of MW irradiation-induced oxidative stress not only suppresses implantation, but it may also lead to deformity of the embryo in case pregnancy continues. We also suggest that MW radiation-induced oxidative stress by increasing ROS production in the body may lead to DNA strand breakage in the brain cells and implantation failure/resorption or abnormal pregnancy in mice.

Keywords Microwave radiation · Reactive oxygen species (ROS) · Nitric oxide · Antioxidant enzyme activity · Implantation failure

Introduction

Microwaves (MW) are non-ionizing electromagnetic radiation (EMR) (wavelength ranging from 1 mm to 1 m and frequency between 0.3 and 300 GHz), which unlike ionizing radiation, do not contain sufficient energy to break the bond or chemically change the substances by ionization. In general, non-ionizing radiations are associated with two major potential hazards, i.e., electrical and biological. In recent times, the level of EMR in our environment has increased manifold due to a large-scale expansion of communication networks such as mobile phones, base stations, WLAN, Wi-Fi, Wi-MAX, etc. Radiations emitted from these modern devices are reported to induce various types of biological effects which are of great concern to human health due to its increased use in daily life. MW radiation primarily increases the temperature of the biological system, i.e., thermal effects [1], but its nonthermal effects have also been noted and studied in detail [2–8]. Nonthermal effects occur when the intensity of the MW radiation is sufficiently low so that the amount of energy involved would not significantly increase the temperature of a cell, tissue, or an organism, but may induce some physical or biochemical changes [9]. Prolonged exposure to low intensity 2.45 GHz microwave radiation may affect the cholinergic activity in the rat [2], brain development in mice [10], DNA breakage in rat brain [11], and histone kinase activity in rat [12], which results in neurological problems and reproductive disorders [13–15], in addition to changes in hematopoiesis of pregnant mice [16] and micronucleated erythrocytes in rats [17]. The International Agency for Research on Cancer has also kept radiofrequency electromagnetic fields in the list of factors causing cancer to humans. Some studies performed in this context suggest that people heavily exposed to these radiations are more prone to nonmalignant tumors [18]. It has been reported that mobile phone or cell phone radiation (a type of MW radiation) causes changes in cognitive function [19]. A German study has indicated an increase in cancer around base stations. Mobile phones use electromagnetic radiation in a microwave range (2G—900/1,800 MHz, 3G—2,100 MHz frequency band) which some believe may be harmful to human health. People living close to 2G and mostly 3G mobile phone masts or base stations frequently report symptoms of electromagnetic hypersensitivity such as dizziness, headaches, skin conditions, allergies, and many other problems. Hardell and groups [20, 21] have reported the health implications of mobile phone exposure (800–2,200 MHz). They found that cell phone users had an increased risk of

Biol Trace Elem Res (2011) 143:1640–1650
DOI 10.1007/s12011-011-8994-0

Selenium and L-Carnitine Reduce Oxidative Stress in the Heart of Rat Induced by 2.45-GHz Radiation from Wireless Devices

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Received: 29 December 2010 / Accepted: 2 February 2011 /
Published online: 1 March 2011

Abstract The aim of this study was to investigate the possible protective role of selenium and L-carnitine on oxidative stress induced by 2.45-GHz radiation in heart of rat. For this purpose, 30 male Wistar Albino rats were equally divided into five groups namely controls, sham controls, radiation-exposed rats, radiation-exposed rats treated with intraperitoneal injections of sodium selenite at a dose of 1.5 mg/kg/day, and radiation-exposed rats treated with intraperitoneal injections of L-carnitine at a dose of 1.5 mg/kg/day. Except for the controls and sham controls, the animals were exposed to 2.45-GHz radiation during 60 min/day for 28 days. The lipid peroxidation (LP) levels were higher in the radiation-exposed groups than in the control and sham control groups. The lipid peroxidation level in the irradiated animals treated with selenium and L-carnitine was lower than in those that were only exposed to 2.45-GHz radiation. The concentrations of vitamins A, C, and E were lower in the irradiated-only group relative to control and sham control groups, but their concentrations were increased in the groups treated with selenium- and L-carnitine. The activity of glutathione peroxidase was higher in the selenium-treated group than in the animals that were irradiated but received no treatment. The erythrocyte-reduced glutathione and β-carotene concentrations did not change in any of the groups. In conclusion, 2.45-GHz

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electromagnetic radiation caused oxidative stress in the heart of rats. There is an apparent protective effect of selenium and L-carnitine by inhibition of free radical formation and support of the antioxidant redox system.

Keywords 2.45-GHz electromagnetic radiation · Oxidative stress · Antioxidant enzymes · Antioxidant vitamins · L-Carnitine · Selenium

Introduction

Many devices that emit 2.45-GHz radiation are in use for industrial, scientific, medical, military, and domestic purposes present a potential health and environmental problem [1]. Several studies have suggested that biological systems could exhibit a specific sensitivity to 2.45-GHz electromagnetic radiation [2–4]. Other studies were extended to electromagnetic radiation (EMR) generated from common household devices like microwave ovens, wireless access points, and computers which were also shown to have negative health effects, and that antioxidants showed a protective effect on 900-MHz mobile phone emissions [5, 6].

These types of radiation positively correlate to generation of oxygen-derived radicals (ROS) such as superoxide radical ions. The heart is the organ that consumes the greatest amount of oxygen, which makes it at greatest risk of oxidative stress and, in consequence, most susceptible to oxidative damage [1, 6, 7]. Superoxide ion radicals and other free radical species may be involved in the interactions of EMR on biological systems, but the cellular and molecular mechanisms involved in this process are still poorly understood [8, 9].

Exposure to 2.45-GHz EMR caused an increase in lipid peroxidation levels and a decrease in the activity of enzymes and vitamins that prevent or protect against lipid peroxidation in blood [8] and brain [9].

The body has enzymatic and non-enzymatic antioxidant systems. Enzymatic antioxidants neutralize excessive ROS, preventing them from damaging the cellular structure. Among those are superoxide dismutase (SOD), catalase (CAT), and glutathione peroxidase (GSH-Px) [10, 11]. In particular, GSH-Px is a selenium (Se)-containing enzyme responsible for the reduction of hydro- and organic peroxides in the presence of reduced glutathione (GSH) [12]. Se is also required for the catalytic activity of another critical antioxidant enzyme, mammalian thioredoxin reductase (TR). Along with vitamins C and E, Se is widely recognized as an essential part of the antioxidant system [11–13].

L-Carnitine (L-Car) is a low molecular weight compound obtained from the diet or biosynthesized from lysine and methionine. It has been identified in a variety of mammalian tissues and has an essential role in the mitochondrial oxidation of long-chain fatty acids through the action of specialized acyltransferases. Other roles for carnitine include buffering of the acyl coenzyme A/coenzyme A ratio, branched-chain amino acid metabolism, removal of excess acyl groups, and peroxisomal fatty acid oxidation [14]. L-Car has also been found to attenuate free radical-induced oxidative stress in various pathological conditions of heart [15]. The growing body of evidence about carnitine function in heart has led to increased understanding and identification of heart disorders associated with altered carnitine metabolism. However, there is no report on L-Car and 2.45 GHz-induced antioxidant redox system in heart.

There are no reports on the effects of wireless devices emitting 2.45 GHz radiation in the heart of experimental animals. The aim of the present study was to investigate the effects of

Electromagnetic Biology and Medicine, June 2013; 32(2): 200–208

ISSN 1536-8378 print/ISSN 1536-8386 online
DOI: 10.3109/15368378.2013.776430

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Wi-Fi technology – an uncontrolled global experiment on the health of mankind

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The twenty-first century is marked with exponentially increasing development of technologies that provide wireless communications. To the pollution of the atmosphere with radio and TV signals, not only satellite communications but also any varieties of the Wi-Fi networks are added. By 2010 in the USA, 285 million mobile phone subscribers have been registered (for a little bit more than 300 million inhabitants). The estimate for the world is more than 5 billion mobile phone users at approximately 7 billion people living on this planet. Approximately 2 years ago, the International Agency of Research on Cancer (IARC) classified the electromagnetic fields used in mobile communication as a possible cancerogene. This paper discusses the potential health hazard and lack of scientific assessment and regulatory actions in protection of the life on the planet.

Keywords: WiFi, pollution, hazard, Radiofrequency electromagnetic fields

The problem: Ionizing versus nonionizing radiation

Contemporary science is increasingly using and investigating two physical factors such as ionizing and nonionizing radiation, with an attempt t? search for common mechanisms of action and evaluation of the public benefit and health hazard. What is common here is the word "radiation." However, from the viewpoint of physics, these are two different factors that might be found in an environment. Importantly, they act simultaneously, but are discussed separately, entirely neglecting the existing background of the other factor.

It has been well established that ionizing radiation usually provokes effects based on energetic mechanisms and ionization of tissues. This action is characterized with threshold levels and could develop within short time after irradiation. Speaking on ionizing radiation, scientists and public health experts, based on decades of investigation, have come to know about a large variety of unfavorable, potentially harmful effects that developed hours (sometimes days) after irradiation. This was well confirmed in the evaluation of health effects and care for personnel and population after Chernobyl accident a quarter of century ago (Grigoriev, 2012a,b; Sage, 2012). Throughout the world, interest was also excited by the recent Fukushima disaster in March 2011.

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Using the Hill viewpoints from 1965 for evaluating strengths of evidence of the risk for brain tumors associated with use of mobile and cordless phones[1)]

Abstract

Background: Wireless phones, i.e., mobile phones and cordless phones, emit radiofrequency electromagnetic fields (RF-EMF) when used. An increased risk of brain tumors is a major concern. The International Agency for Research on Cancer (IARC) at the World Health Organization (WHO) evaluated the carcinogenic effect to humans from RF-EMF in May 2011. It was concluded that RF-EMF is a group 2B, i.e., a "possible", human carcinogen. Bradford Hill gave a presidential address at the British Royal Society of Medicine in 1965 on the association or causation that provides a helpful framework for evaluation of the brain tumor risk from RF-EMF.

Methods: All nine issues on causation according to Hill were evaluated. Regarding wireless phones, only studies with long-term use were included. In addition, laboratory studies and data on the incidence of brain tumors were considered.

Results: The criteria on strength, consistency, specificity, temporality, and biologic gradient for evidence of increased risk for glioma and acoustic neuroma were fulfilled. Additional evidence came from plausibility and analogy based on laboratory studies. Regarding coherence, several studies show increasing incidence of brain tumors, especially in the most exposed area. Support for the experiment came from antioxidants that can alleviate the generation of reactive oxygen species involved in biologic effects, although a direct mechanism for brain tumor carcinogenesis has not been shown. In addition, the finding of no increased risk for brain tumors in subjects using the mobile phone only in a car with an external antenna is supportive evidence. Hill did not consider all the needed nine viewpoints to be essential requirements.

Conclusion: Based on the Hill criteria, glioma and acoustic neuroma should be considered to be caused by RF-EMF emissions from wireless phones and regarded as carcinogenic to humans, classifying it as group 1 according to the IARC classification. Current guidelines for exposure need to be urgently revised.

Keywords: acoustic neuroma; causation; glioma; Hill criteria; wireless phones.

[1)]Based on a presentation at the Corporate Interference with Science and Health: Fracking, Food and Wireless, Scandinavia House, New York City, March 13 and 14, 2013.

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Background

Mobile phones have been used since the early 1980s, and the Scandinavian countries were among the first in the world to adopt this technology. At first, analog phones [Nordic Mobile Telephone System (NMT)] were used, but in the early 1990s, the digital system [Global System for Mobile Communication (GSM)] was introduced. The analog system was definitely closed down in Sweden on December 31, 2007. Nowadays, mobile phones are used more than landline phones in Sweden (1). Worldwide, estimates of 5.9 billion mobile phone subscriptions were reported at the end of 2011 by the International Telecommunication Union (2).

Desktop cordless telephones have been used in Sweden since the end of the 1980s, first using the analog system, but since the 1990s, the digital variant was used. They are very common both in homes and at workplaces, overtaking telephones connected to landlines.

Wireless phones, i.e., mobile phones and cordless phones, emit radiofrequency electromagnetic fields (RF-EMF) when used. Cordless phones should be given an equal consideration as mobile phones when this type of exposure is assessed. In fact, this has not been the case except for the Hardell group studies in Sweden (3–8). When used, the handheld mobile phones gives exposure

Electromagnetic Biology and Medicine, 29: 31–35, 2010

ISSN: 1536-8378 print/1536-8386 online
DOI: 10.3109/15368371003685363

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Mobile Phone Mast Effects on Common Frog (*Rana temporaria*) Tadpoles: The City Turned into a Laboratory

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*An experiment has been made exposing eggs and tadpoles of the common frog (*Rana temporaria*) to electromagnetic radiation from several mobile (cell) phone antennae located at a distance of 140 meters. The experiment lasted two months, from the egg phase until an advanced phase of tadpole prior to metamorphosis. Measurements of electric field intensity (radiofrequencies and microwaves) in V/m obtained with three different devices were 1.8 to 3.5 V/m. In the exposed group (*n = 70*), low coordination of movements, an asynchronous growth, resulting in both big and small tadpoles, and a high mortality (90%) was observed. Regarding the control group (*n = 70*) under the same conditions but inside a Faraday cage, the coordination of movements was normal, the development was synchronous, and a mortality of 4.2% was obtained. These results indicate that radiation emitted by phone masts in a real situation may affect the development and may cause an increase in mortality of exposed tadpoles. This research may have huge implications for the natural world, which is now exposed to high microwave radiation levels from a multitude of phone masts.*

Keywords Electromagnetic pollution; Microwaves; Phone masts; *Rana temporaria*; Tadpoles.

Introduction

In recent years, a large number of mobile phone antennae have been installed, especially in urban areas. The scientific literature review shows that pulsed telephony microwave radiation may produce effects, especially on nervous, cardiovascular, immune, and reproductive systems (Balmori, 2009), but few studies on effects from phone masts on wildlife in the cities have been conducted (Balmori, 2005; Balmori and Hallberg, 2007; Everaert and Bauwens, 2007).

Concerning the effects of electromagnetic radiation on amphibians, several investigations in the laboratory have been conducted (Levengood, 1969; Landesman and Douglas, 1990; Grefner et al., 1998), but as far as we know there have not been any published studies on effects from phone antennae on amphibian populations in their natural habitat.

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Review

David O. Carpenter*

Human disease resulting from exposure to electromagnetic fields[1)]

Abstract: Electromagnetic fields (EMFs) include everything from cosmic rays through visible light to the electric and magnetic fields associated with electricity. While the high frequency fields have sufficient energy to cause cancer, the question of whether there are human health hazards associated with communication radiofrequency (RF) EMFs and those associated with use of electricity remains controversial. The issue is more important than ever given the rapid increase in the use of cell phones and other wireless devices. This review summarizes the evidence stating that excessive exposure to magnetic fields from power lines and other sources of electric current increases the risk of development of some cancers and neurodegenerative diseases, and that excessive exposure to RF radiation increases risk of cancer, male infertility, and neurobehavioral abnormalities. The relative impact of various sources of exposure, the great range of standards for EMF exposure, and the costs of doing nothing are also discussed.

Keywords: cancer; cell phones; male fertility; power lines.

[1)]From: Conference on Corporate Influences on Fracking, Food and Wireless.

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Introduction

Electromagnetic fields (EMFs) are packets of energy that have no mass. The form of EMFs we all know best is visible light. We distinguish red from violet because the EMFs that we see as red have a longer wavelength than those we see as violet, and the visual pigments in our retina distinguishes these colors on the basis of the wavelength. All EMFs travel at the speed of light, and are basically sine waves of different frequencies. As such, an EMF that is of low frequency has a long wavelength, while those with a high frequency have a short wavelength. The energy of a particular EMF is a function of its frequency, such that the higher the frequency the greater the energy. Figure 1 shows the electromagnetic spectrum.

At the high end of the EMF spectrum, we have X-rays, gamma rays, and cosmic rays. These have a very high frequency and a very short wavelength. They also have very high energy levels, sufficient to directly damage DNA and every other biological molecule, including breaking water molecules. Given that many of these actions are mediated by breaking water molecules into reactive oxygen species (ROS) or free radicals, these high energy EMFs are identified as a form of "ionizing" radiation. They can induce similar kinds of cellular damage as do particulate ionizing radiation (α, β, and γ particles). We are all continuously exposed to ionizing EMFs at low exposure levels, which come from cosmic rays from space as well as from the disintegration of natural radioactive isotopes in our environment and even within our bodies. Ionizing radiation, whether in the form of EMFs or particulate radiation, causes cellular damage and increases the risk of a variety of diseases, particularly cancer and birth defects. There is some evidence in support of the hypothesis that the basic mechanism behind the aging process is the accumulation of cell damage coming from ionizing radiation and other sources (1).

As frequencies are reduced from the ionizing portion of the electromagnetic spectrum we have ultraviolet radiation, which is known to induce skin cancer with excessive exposure, then visible light and infrared radiation which heat the earth. Clearly, life on earth as we know it would not be possible without visible light and infrared radiation. This fact has led many to assume that there could not possibly be adverse health effects from frequencies below visible light and infrared EMFs.

Below the infrared is the radiofrequency (RF) portion of the spectrum, which includes microwaves and those frequencies used primarily for communication (AM and FM radio, television, cell phone, radar and all forms of "wireless" communication). The ability to tune in to a specific radio station is a function of the particular frequency at which that station broadcasts. Almost everyone is continuously bathed in RF radiation coming from radio and

Science of the Total Environment 572 (2016) 554–569

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Radiofrequency radiation injures trees around mobile phone base stations

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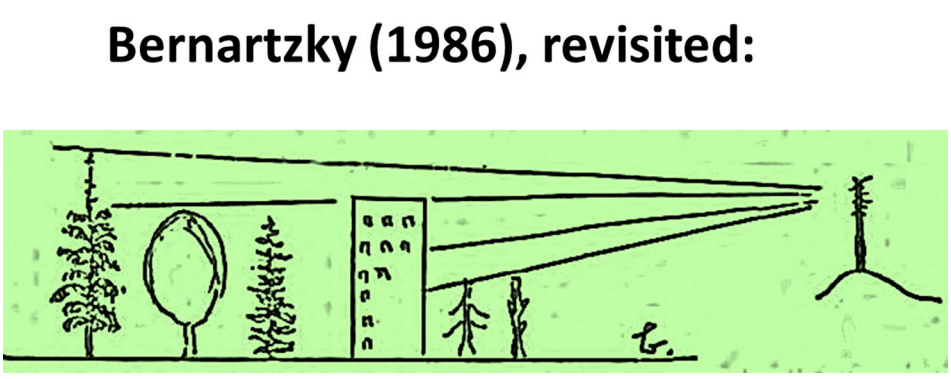
HIGHLIGHTS

- High frequency nonionizing radiation is becoming increasingly common.
- This study found a high level of damage to trees in the vicinity of phone masts.
- Deployment has been continued without consideration of environmental impact.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 6 June 2016
Received in revised form 19 July 2016
Accepted 6 August 2016
Available online xxxx

Editor: D. Barcelo

Keywords:
Electromagnetic radiation
Effects on trees
Phone masts
Radiofrequencies

ABSTRACT

In the last two decades, the deployment of phone masts around the world has taken place and, for many years, there has been a discussion in the scientific community about the possible environmental impact from mobile phone base stations. Trees have several advantages over animals as experimental subjects and the aim of this study was to verify whether there is a connection between unusual (generally unilateral) tree damage and radiofrequency exposure. To achieve this, a detailed long-term (2006–2015) field monitoring study was performed in the cities of Bamberg and Hallstadt (Germany). During monitoring, observations and photographic recordings of unusual or unexplainable tree damage were taken, alongside the measurement of electromagnetic radiation. In 2015 measurements of RF-EMF (Radiofrequency Electromagnetic Fields) were carried out. A polygon spanning both cities was chosen as the study site, where 144 measurements of the radiofrequency of electromagnetic fields were taken at a height of 1.5 m in streets and parks at different locations. By interpolation of the 144 measurement points, we were able to compile an electromagnetic map of the power flux density in Bamberg and Hallstadt. We selected 60 damaged trees, in addition to 30 randomly selected trees and 30 trees in low radiation areas (n = 120) in this polygon. The measurements of all trees revealed significant differences between the damaged side facing a phone mast and the opposite side, as well as differences between the exposed side of damaged trees and all other groups of trees in both sides. Thus, we found that side differences in measured values of power flux density corresponded to side differences in damage. The 30 selected trees in low radiation areas (no visual

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http://dx.doi.org/10.1016/j.scitotenv.2016.08.045

Exp Oncol 2011
33, 2, 62–70

REVIEW

Experimental ONCOLOGY

LONG-TERM EXPOSURE TO MICROWAVE RADIATION PROVOKES CANCER GROWTH: EVIDENCES FROM RADARS AND MOBILE COMMUNICATION SYSTEMS

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In this review we discuss alarming epidemiological and experimental data on possible carcinogenic effects of long term exposure to low intensity microwave (MW) radiation. Recently, a number of reports revealed that under certain conditions the irradiation by low intensity MW can substantially induce cancer progression in humans and in animal models. The carcinogenic effect of MW irradiation is typically manifested after long term (up to 10 years and more) exposure. Nevertheless, even a year of operation of a powerful base transmitting station for mobile communication reportedly resulted in a dramatic increase of cancer incidence among population living nearby. In addition, model studies in rodents unveiled a significant increase in carcinogenesis after 17-24 months of MW exposure both in tumor-prone and intact animals. To that, such metabolic changes, as overproduction of reactive oxygen species, 8-hydroxi-2-deoxyguanosine formation, or ornithine decarboxylase activation under exposure to low intensity MW confirm a stress impact of this factor on living cells. We also address the issue of standards for assessment of biological effects of irradiation. It is now becoming increasingly evident that assessment of biological effects of non-ionizing radiation based on physical (thermal) approach used in recommendations of current regulatory bodies, including the International Commission on Non-Ionizing Radiation Protection (ICNIRP) Guidelines, requires urgent reevaluation. We conclude that recent data strongly point to the need for re-elaboration of the current safety limits for non-ionizing radiation using recently obtained knowledge. We also emphasize that the everyday exposure of both occupational and general public to MW radiation should be regulated based on a precautionary principles which imply maximum restriction of excessive exposure.

***Key Words*: non-ionizing radiation, radiofrequency, tumor, risk assessment, safety limits, precautionary principle.**

INTRODUCTION

Electromagnetic radiation (EMR) became one of the most significant and fastest growing environmental factors due to intensive development of communication technologies during the last decades. Currently, according to expert estimations, the level of electromagnetic radiation from artificial sources exceeds the level of natural electromagnetic fields by thousand folds. The active development of mobile communication technologies over the world will only raise this level further. In this connection the problem of possible adverse effects of anthropogenic EMR on human health and particularly strictest assessment of possible carcinogenic effects of EMR is extremely important.

In August 2007 an international working group of renowned scientists and public health experts released a report on electromagnetic fields (EMF) and human health [1]. It raised a serious concern about safety limits for public electromagnetic irradiation from power lines, cell phones, radars, and other sources of EMF exposure in daily life. The authors concluded that the existing public safety limits were inadequate to protect public health. Moreover, very recently a vast number of new extremely important studies in this field have been published. Importantly, nowadays the problem is discussed on highest political level over the world. It appears that the most sound political document in Europe is a European Parliament Resolution from April 2, 2009 (*www.europarl.europa.eu*), where the direct appeals to activate the research and business strategy for effective solving of the problem over the member states were indicated.

In this review we would like to analyze the results of studies on specific biological effects of microwaves (MW), both epidemiological and experimental that deal with cancer promotion by long term low intensity microwave irradiation of human/animal beings. We will concentrate on unequivocal studies and will not analyze ambiguous data. For additional analysis of microwave risks we can recommend recently published reviews [2–10].

MICROWAVES OF RADARS AND MOBILE COMMUNICATION SYSTEMS

Microwaves are non-ionizing electromagnetic radiation. That means MW is a type of electromagnetic radiation which does not carry enough energy

Received: March 21, 2011.

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Abbreviations used: 8-OH-dG — 8-hydroxi-2-deoxyguanosine; EGF — epidermal growth factor; EMF — electromagnetic field; EMR — electromagnetic radiation; ERK — extracellular-signal-regulated kinase; GSM — Global System for Mobile communication; ICNIRP — International Commission on Non-Ionizing Radiation Protection; MW — microwaves; NHL — Non-Hodgkin lymphoma; ODC — ornithine decarboxylase; OER — observed expected ratio; OR — odds ratio; ROS — reactive oxygen species; SAR — specific absorption rate; SIR — standardized incidence ratio; SMR — standardized mortality ratio; WHO — the World Health Organization.

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Impacts of radio-frequency electromagnetic field (RF-EMF) from cell phone towers and wireless devices on biosystem and ecosystem – a review

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Accepted: 3rd Dec 2012, Published: 6th Jan 2013

Abstract
This paper summarizes the effect of radio-frequency electromagnetic field (RF-EMF) from cell towers and wireless devices on the biosphere. Based on current available literature, it is justified to conclude that RF-EMF radiation exposure can change neurotransmitter functions, blood-brain barrier, morphology, electrophysiology, cellular metabolism, calcium efflux, and gene and protein expression in certain types of cells even at lower intensities. The biological consequences of such changes remain unclear. Short-term studies on the impacts of RF-EMF on frogs, honey bees, house sparrows, bats, and even humans are scare and long-term studies are non-existent in India. Identification of the frequency, intensity, and duration of non-ionizing electromagnetic fields causing damage to the biosystem and ecosystem would evolve strategies for mitigation and would enable the proper use of wireless technologies to enjoy its immense benefits, while ensuring one's health and that of the environment.

Keywords: Radio-frequency electromagnetic field; cell phone tower; power density; SAR; non-ionizing radiation; non-thermal.

Introduction

There has been an unprecedented growth in the global communication industry in recent years which has resulted in a dramatic increase in the number of wireless devices. Mobile services were launched in India in 1995 and it is one of the fastest growing mobile telephony industries in the world. According to the Telecom Regulatory Authority of India (TRAI, 2012), the composition of telephone subscribers using wireless form of communication in urban area is 63.27% and rural area is 33.20%. By 2013, it is estimated that more than one billion people will be having cell phone connection in India. This has led to the mushrooming of supporting infrastructure in the form of cell towers which provide the link to and from the mobile phone. With no regulation on the placement of cell towers, they are being placed haphazardly closer to schools, creches, public playgrounds, on commercial buildings, hospitals, college campuses, and terraces of densely populated urban residential areas. Hence, the public is being exposed to continuous, low intensity radiations from these towers. Since the electromagnetic radiations, also known as electrosmog cannot be seen, smelt or felt, one would not realize their potential harm over long periods of exposure until they manifest in the form of biological disorders. Various studies have shown the ill-effects of radio-frequency electromagnetic field (RF-EMF) on bees, fruit flies, frogs, birds, bats, and humans, but the long-term studies of such exposures are inconclusive and scarce, and almost non-existent in India (MOEF, 2010; DoT, 2010). In 2011, International Agency for Research on Cancer (IARC), part of WHO, designated RF-EMF from cell phones as a "possible human carcinogen" Class 2B (WHO, 2011). Cancer, diabetes, asthma, infectious diseases, infertility, neurodegenerative disorders, and even suicides are on the rise in India. This invisible health hazard pollution (IHHP) is a relatively new environmental threat.

Electromagnetic radiation, in the form of waves of electric and magnetic energy, have been circulating together through space. The electromagnetic spectrum includes radio waves, microwaves, infrared rays, light rays, ultraviolet rays, X-rays, and gamma rays (ARPANSA, 2011;